Micro-PIXE Analysis of Arctic Char, *Salvelinus alpinus*, Otoliths from Quttinirpaaq National Park, Nunavut

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ABSTRACT

Babaluk, J.A., C.L. Evans, and J.D. Reist. 2002. Micro-PIXE analysis of Arctic char, *Salvelinus alpinus*, otoliths from Quttinirpaaq National Park, Nunavut. Can. Data Rep. Fish. Aquat. Sci. 1092: xiv + 143 p.

Micro-PIXE analysis (line-scans) was used to determine the distribution of strontium (Sr) and zinc (Zn) in otoliths of Arctic char, *Salvelinus alpinus*, from 10 lakes in Quttinirpaaq National Park, Ellesmere Island, Nunavut. Profiles of these distributions are presented. Trace element (Sr and Zn) concentrations in otolith cores from these fish were also determined by micro-PIXE analysis (point analysis) and are tabulated.

Key words: anadromy; life history; otolith microchemistry; scanning proton microprobe; trace elements.

RÉSUMÉ

Babaluk, J.A., C.L. Evans, and J.D. Reist. 2002. Micro-PIXE analysis of Arctic char, *Salvelinus alpinus*, otoliths from Quttinirpaaq National Park, Nunavut. Can. Data Rep. Fish. Aquat. Sci. 1092: xiv + 143 p.

Nous avons utilisé la micro-analyse PIXE par balayage pour déterminer la répartition du (Sr) et du zinc (Zn) dans des otolithes d'ombles chevaliers (*Salvelinus alpinus*) capturés dans dix lacs du parc national Quttinirpaaq, situé sur l'île d'Ellesmere (Nunavut). Nous présentons des profils de ces répartitions. Nous avons aussi mesuré les concentrations des éléments traces Sr et Zn dans le centre des otolithes de ces poissons par micro-analyse PIXE ponctuelle : les résultats sont présentés dans un tableau.

Mots clés: anadromie; cycle vital; microchimie des otolithes; microsonde à proton à balayage; éléments traces.

INTRODUCTION

A basic understanding of the biology and diversity of the Arctic char, *Salvelinus alpinus*, populations in Quttinirpaaq National Park, formerly Ellesmere Island National Park Reserve, is fundamental to Parks Canada's long-term conservation and management plans for these fish (Parks Canada 1994). Arctic char is the only freshwater fish species in the Canadian High Arctic including Quttinirpaaq National Park (Scott and Crossman 1973; Parks Canada 1994). However, the species exhibits great diversity at a number of levels below that of species including: a) life history type (e.g., anadromous or non-anadromous), b) ecological type (e.g., pelagic or benthic forms), c) trophic type (e.g., planktivore or piscivore), d) evolutionary lineages (e.g., subspecies, biological stocks), as well as, e) variants within many of the above types (e.g., life history variability). This diversity can be observed through a number of techniques, but is best understood using several complementary approaches such as: a) morphology (e.g., body form and function), b) genetics (e.g., delineation of groups using DNA chemistry), c) stable isotopes and diet (e.g., trophic pattern), d) population dynamics (e.g., age and size structure), and e) otolith microchemistry (e.g., life history types, stock discrimination).

Fisheries and Oceans Canada (DFO), in collaboration with Parks Canada, has assessed the diversity in Quttinirpaaq National Park Arctic char populations since 1990. In 1990, a study on contaminants in Lake Hazen sediments was conducted (Muir et al. 1995). At the same time, Arctic char were also collected for a study on contaminants in muscle tissue (Muir and Lockhart 1992; Muir and Lockhart 1993). Between 1992 and 1998, DFO, assisted by Parks Canada, intermittently assessed Arctic char populations within Quttinirpaaq National Park, in particular Lake Hazen Arctic char. Reist et al. (1995) showed that there were at least two morphotypes or forms of Arctic char in Lake Hazen (a small and a large form). Some results of other studies have been reported by Brown Gladden et al. (1995), Reist et al. (1995), Babaluk et al. (1997), Babaluk et al. (2001), Babaluk et al. (2002) and Guiguer et al. (2002). Before this area of northern Ellesmere Island became initially, a national park reserve and then, a national park, it had only been visited by two other groups of fisheries researchers: 1) in 1958, a group under the auspices of the Defence Research Board of Canada collected biological information on the Arctic char in Lake Hazen (Hunter 1960; Johnson 1983), and 2) in 1981, DFO biologists collected additional information on Lake Hazen Arctic char (Johnson 1983).

Otoliths ("ear stones") are small, paired structures found in a fish's inner ear used to sense orientation and acceleration. They are composed mainly of a calcium carbonate (aragonite) and protein matrix; but trace elements similar to calcium (Ca), such as strontium (Sr) and zinc (Zn), can be incorporated into or replace Ca in the otolith (Degens et al. 1969). The Ca and trace elements are derived mainly from the waters that the fish inhabits (Ichii and Mugiya 1983). Otoliths do not undergo resorption during the life of the fish (Simkiss 1974) and thus provide an elemental record of the fish's life.

Sea water contains, on average, 8.0 $mg \cdot L^{-1}$ Sr whereas freshwater contains, on average, 0.1 $mg \cdot L^{-1}$ Sr (Rosenthal et al. 1970). Local freshwater Sr concentrations also can vary. For example, in Quttinirpaaq National Park lakes, Sr concentrations range from 0.033 - 0.329 $mg \cdot L^{-1}$ (Babaluk et al. 1999). Sr concentrations in otoliths closely reflect environmental levels of Sr (Babaluk et al. 1998) and thus provide information on the types of environments occupied at particular times of life. This can be used to reconstruct life history and also to differentiate specific environments occupied.

Previous studies using micro-**P**roton-Induced **X**-ray **E**mission (micro-PIXE) analysis of Sr in Arctic char otoliths showed that differences in Sr concentrations can retrospectively indicate anadromous behaviour or, in the case of Lake Hazen Arctic char, indicated non-andromous behaviour (Babaluk et al. 1997) and, in the case of Dolly Varden, *S. malma*, provided details regarding the habitats occupied early in a fish's life (Babaluk et al. 1998).

Another micro-PIXE study, incorporating data published in this report, showed that Zn has a typically oscillatory variation that corresponds to the annular structure of Arctic char otoliths (Halden et al. 2000). Incorporation of Zn is linked to nutrient uptake in the fish so the concentration of Zn in the otolith must, in part, be a proxy for nutrient availability in the environment and perhaps the productivity of a particular environment. Zinc is an important trace nutrient that is necessary for the development of fish gonads (Lall 1989). The onset of sexual maturity

and the development of gonads will likely alter the metabolic distribution of Zn and this may be recorded in the otolith.

As part of the ongoing assessment of Arctic char populations in Quttinirpaaq National Park, we extended the otolith microchemistry study to: a) determine the extent of anadromy (if any) existing within Quttinirpaaq National Park Arctic char populations and b) provide additional trace element information, in particular Sr and Zn, to assist in discriminating stocks or populations. A summary of this work was presented at the Ninth International Conference on Particle-Induced X-ray Emission and its Analytical Applications, June 8 - 12, 2001 at the University of Guelph, Guelph, Ontario (Babaluk et al. 2002). This report presents detailed otolith microchemistry data from the Quttinirpaaq National Park Arctic char samples examined to date.

MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA

Quttinirpaaq National Park is located at the northern end of Ellesmere Island, Nunavut (Fig. 1, left inset). The most northern area of the Park, Cape Aldrich at 83°06'N, is also the most northern point in the Canadian Arctic Archipelago. The park, with an area of 37 775 km^2, is the second largest national park in Canada and is described in detail in Parks Canada (1994).

There are relatively few lakes in Quttinirpaaq National Park and the most productive ones are located on the Hazen Plateau or along the coastal areas of the Grant Land Mountains (Fig. 1, right inset). Most of these lakes provide suitable habitat for some aquatic flora and invertebrates but are too shallow to support Arctic char (Parks Canada 1994). Lakes for this study were chosen because they were known to contain populations of Arctic char (R. Wissink, Parks Canada, Pangnirtung, pers. comm. 1992).

OTOLITH COLLECTION

Otoliths were collected from Arctic char from 10 lakes in Quttinirpaaq National Park: an unnamed lake, hereafter Lake A (82°06'N, 68°37'W) in 1996, Alexandra Lake (81°46'N, 65°32'W) in 1995, an unnamed lake, hereafter Lake B (82°09'N, 68°29'W) in 1996, Craig Lake (81°52'N, 68°47'W) in 1992, Ekblaw Lake (81°40'N, 75°40'W) in 1998, Lake Hazen (81°50'N, 70°25'W) in 1981, 1990, 1992 and 1998, Heintzelman Lake (81°42'N, 66°56'W) in 1995, Kilbourne Lake (81°52'N, 68°25'W) in 1996, Lewis Lake (81°30'N, 74°35'W) in 1998, and Murray Lake (81°20'N, 69°34'W) in 1998 (Fig. 1). Table 1 shows the number of otoliths analysed from each lake.

OTOLITH PREPARATION

One of each pair of otoliths was prepared for micro-PIXE analysis. The otoliths were embedded in epoxy resin and a transverse cut was made such that a dorso-ventral cross section through the core of the otolith was created exposing all annuli (yearly growth increments) (Fig. 2a, b). The posterior half of each otolith was re-embedded in a standard 25 mm diameter leucite, geological probe-mount. The exposed otolith surfaces were sequentially ground (240, 320, 400, and 600 grit silicon carbide), then polished (5, 3, 1, and 0.3 µm aluminum oxide) and finally carbon-coated to prevent charging during microprobe analysis.

MICRO-PIXE ANALYSIS

The general arrangement and operation of the University of Guelph proton microprobe is shown in Figure 2c. Videomicrographs of the otolith sections were used as reference "maps" for the microprobe. A beam of protons, produced by an electrostatic accelerator, is focused on a spot, 5 - 10 µm wide, on the otolith. The excitation volume is a cylinder of approximately 5 - 10 µm in diameter and 30 µm in depth. Ninety percent of the observed Sr X-rays from the aragonite matrix of the otolith originate within a depth of 31 µm (Halden et al. 1996). The resultant X-rays emitted from the otolith were analysed using a silicon/lithium detector equipped with a compound filter of 125 µm Mylar and 106 µm aluminum. One-dimensional line-scans were obtained by rastering the proton beam along a transect from the core area to the dorsal edge of the otolith, incorporating all annuli (see Fig. 2b). Line-scanning of a typical Arctic char otolith took approximately 25 minutes at a proton beam current of 5 - 7 nA. The X-ray spectrum was used to identify trace elements present and the amount of a particular element (Sr and Zn, in this case) was measured by the height

of the X-ray peaks as counts. Three point (spot) analyses and, in some cases, six analyses in the core of each otolith were conducted (see Fig. 2b). Detection limits for Sr and Zn were 1 and 2 parts per million (ppm), respectively. Further details on proton microprobe theory and procedures are provided by Campbell et al. (1995).

DATA PRESENTATION

A summary of micro-PIXE point (spot) analysis data for Sr and Zn from Arctic char otoliths from lakes in Quttinirpaaq National Park is presented in Table 1. Line-scan data (as profiles) for Sr and Zn for Arctic char from these lakes are presented in Figures 3 - 138. For Lake Hazen Arctic char, the putative form of each fish is given when possible (1990, 1992 and 1998 samples). Point analysis data for Sr and Zn for individual Arctic char are presented as part of Figures 3 - 138 (insets). An electronic version of the raw data is available from the senior author c/o Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, Manitoba, R3T 2N6, Canada.

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Table 1. Summary of micro-PIXE point analysis data from Arctic char otoliths from Quttinirpaaq National Park, Nunavut.

Lake	Year	Form	No. of otoliths/ no. of analyses	Mean Sr conc. (ppm ± 1 standard deviation)	Mean Zn conc. (ppm ± 1 standard deviation)
A	1996	all fish	10/30	426 ± 52	64 ± 21
Alexandra	1995	all fish	10/30	165 ± 12	58 ± 19
B	1996	all fish	10/30	490 ± 64	61 ± 18
Craig	1992	all fish	9/39	623 ± 103	69 ± 25
Ekblaw	1998	all fish	10/30	364 ± 49	46 ± 13
Hazen	1981	all fish	15/45	417± 99	58 ± 16
Hazen	1990	all fish	6/36	474 ± 46	64 ± 24
Hazen	1992	small	4/24	533 ± 73	73 ± 27
Hazen	1992	large	13/78	482 ± 102	77 ± 30
Hazen	1998	small	2/6	454 ± 25	56 ± 9
Hazen	1998	large	8/24	323 ± 69	54 ± 19
Hazen	all years	all fish	48/213	456 ± 99	67 ± 26
Heintzelman	1995	all fish	10/30	440 ± 74	56 ± 28
Kilbourne	1996	all fish	10/30	396 ± 35	48 ± 14
Lewis	1998	all fish	10/30	520 ± 81	59 ± 26
Murray	1998	all fish	10/30	179 ± 55	63 ± 16

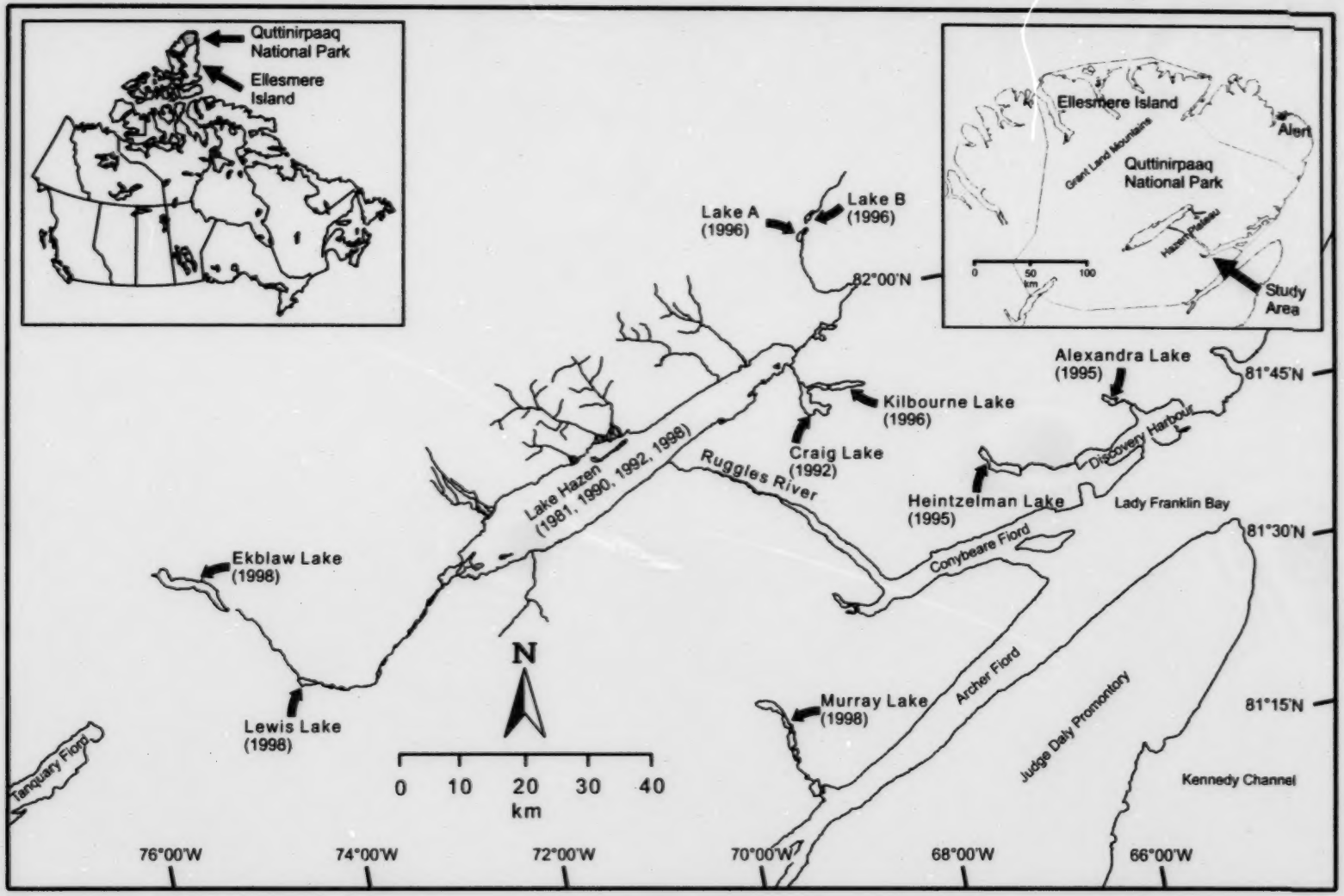

Fig. 1. Map of the Lake Hazen area, Quttinirpaaq National Park, Nunavut showing collection locations of Arctic char used for micro-PIXE analysis and dates (year) fish were collected.

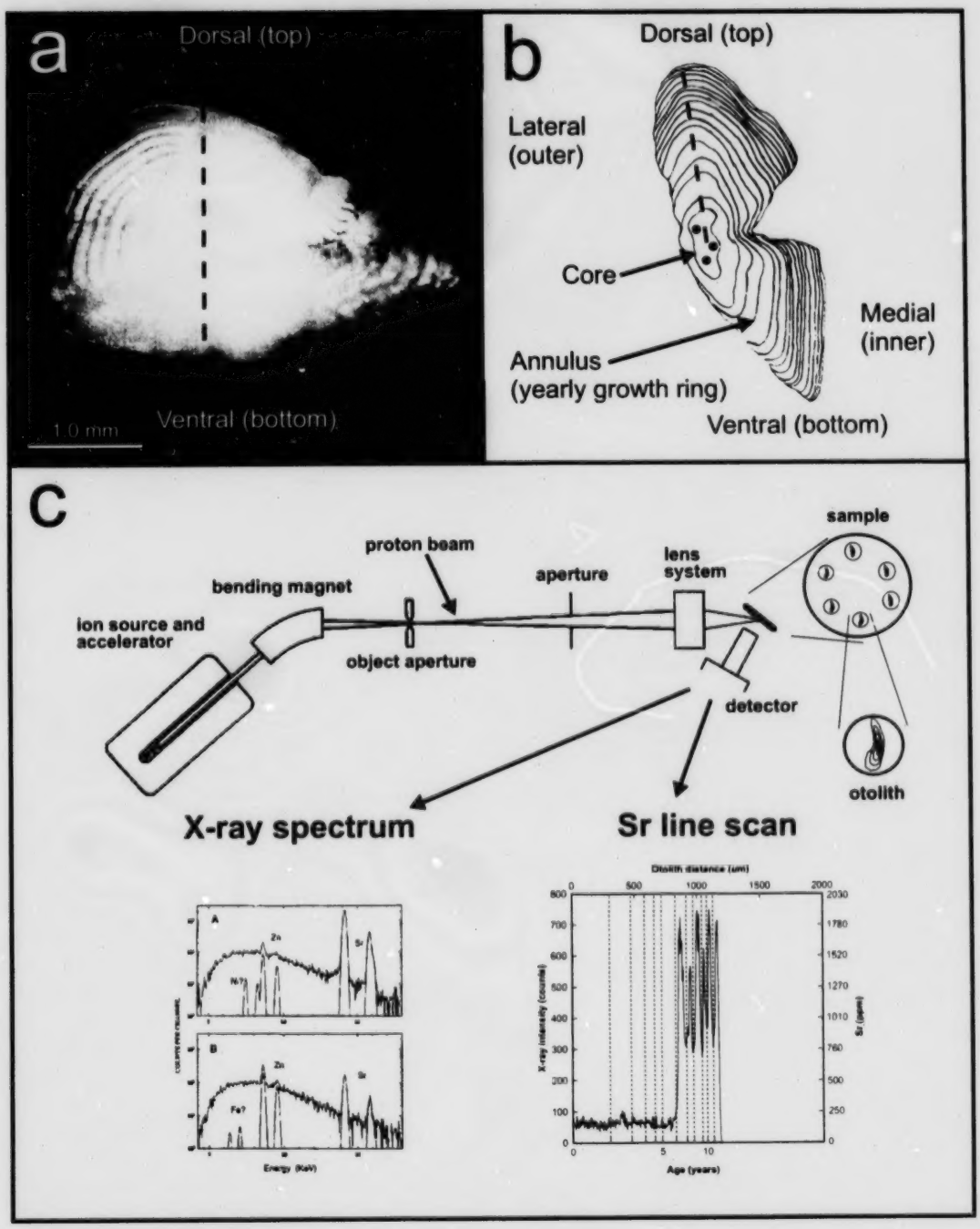

Fig. 2. (a) Lateral side of the external surface of an Arctic char otolith: broken line (---) indicates transverse cut to expose the internal surface, (b) diagram of the exposed surface of an otolith showing typical areas (dots) where point analyses and transect (---) along which line-scan were conducted and (c) diagram showing the general features and arrangement of the University of Guelph scanning proton microprobe.

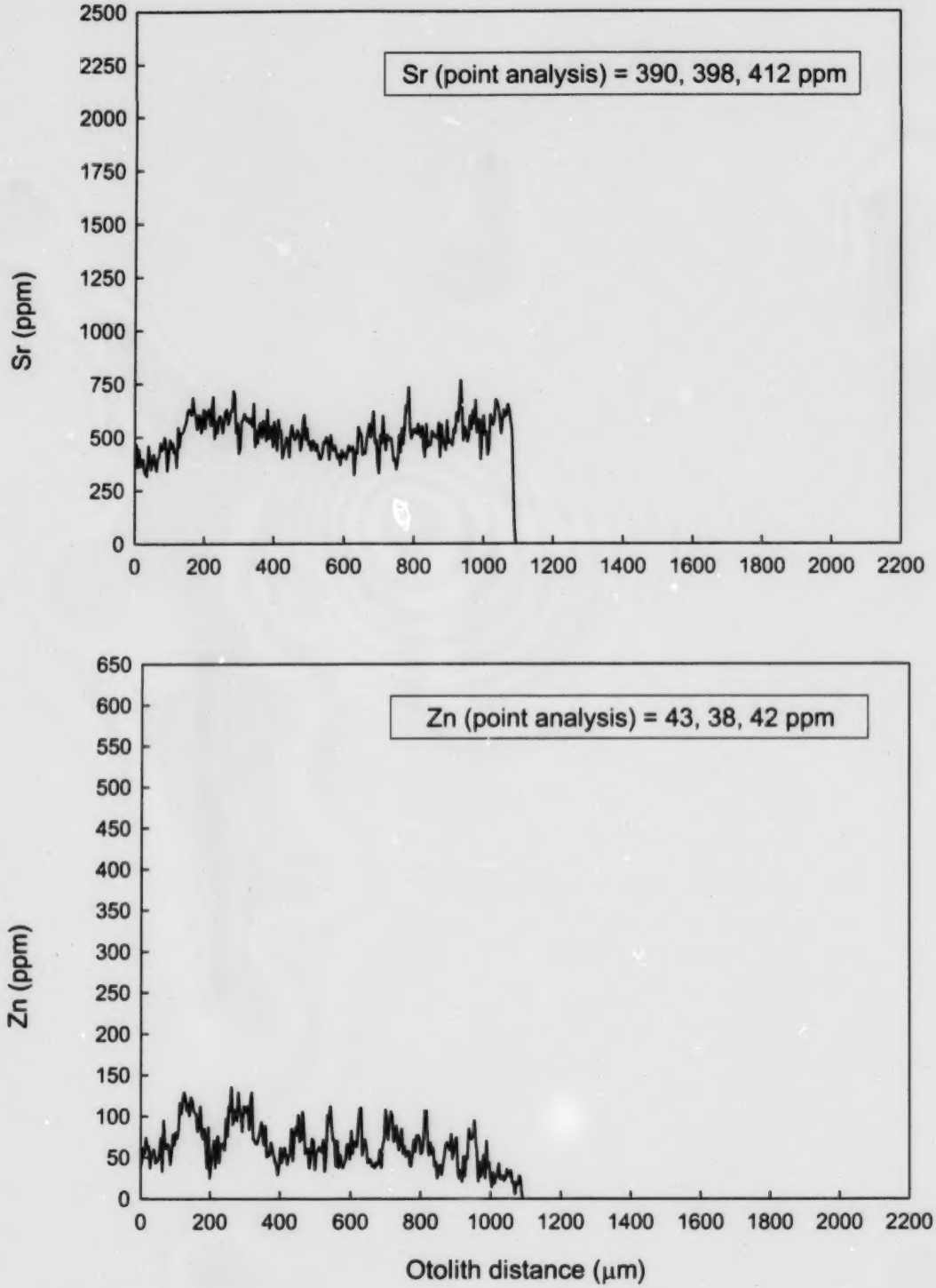

Fig. 3. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (291 mm, 160 g, female, 13 yr) caught in Lake A, May 1996. Point analysis results are also indicated.

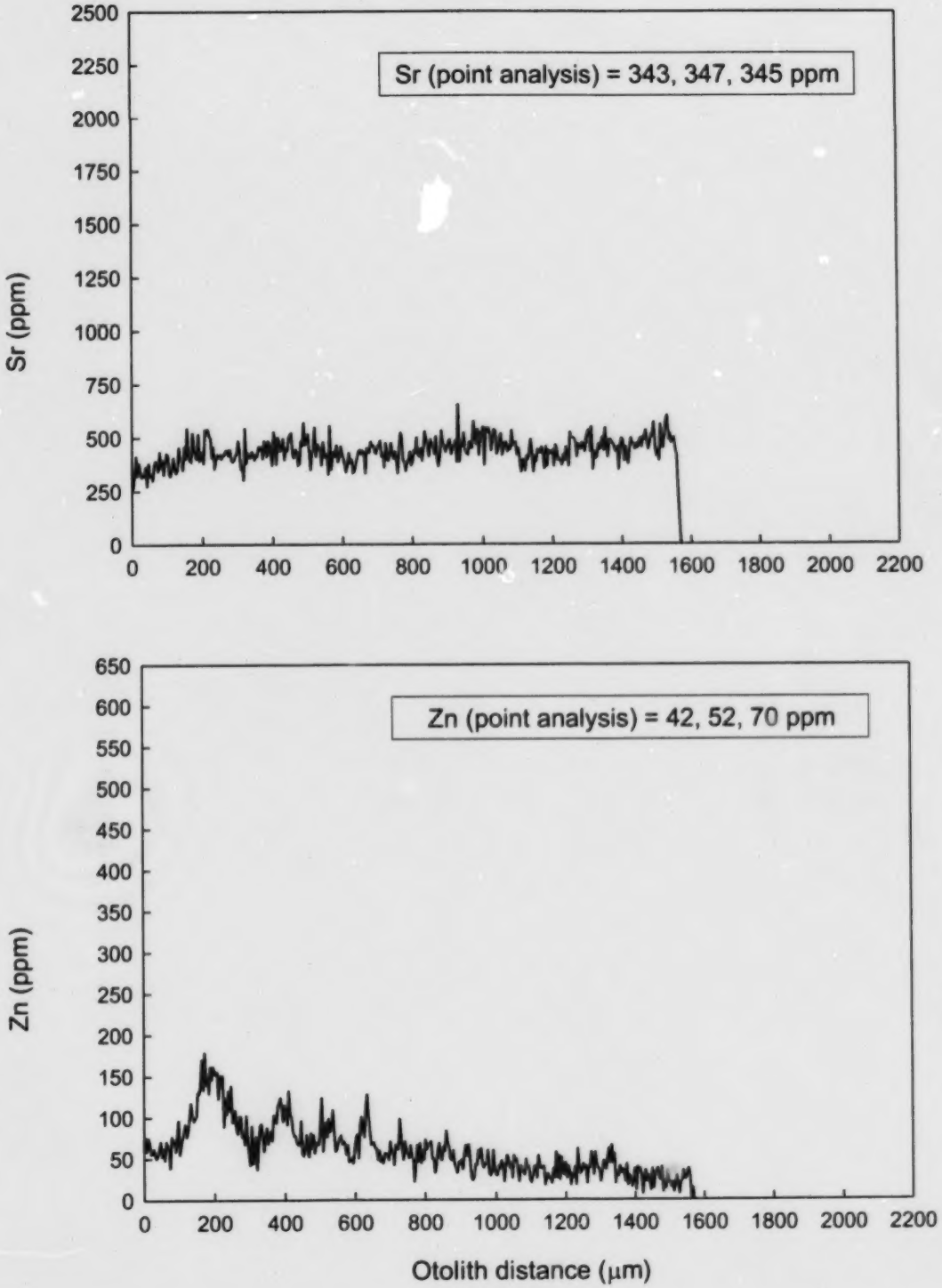

Fig. 4. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (588 mm, 1730 g, male, 28 yr) caught in Lake A, May 1996. Point analysis results are also indicated.

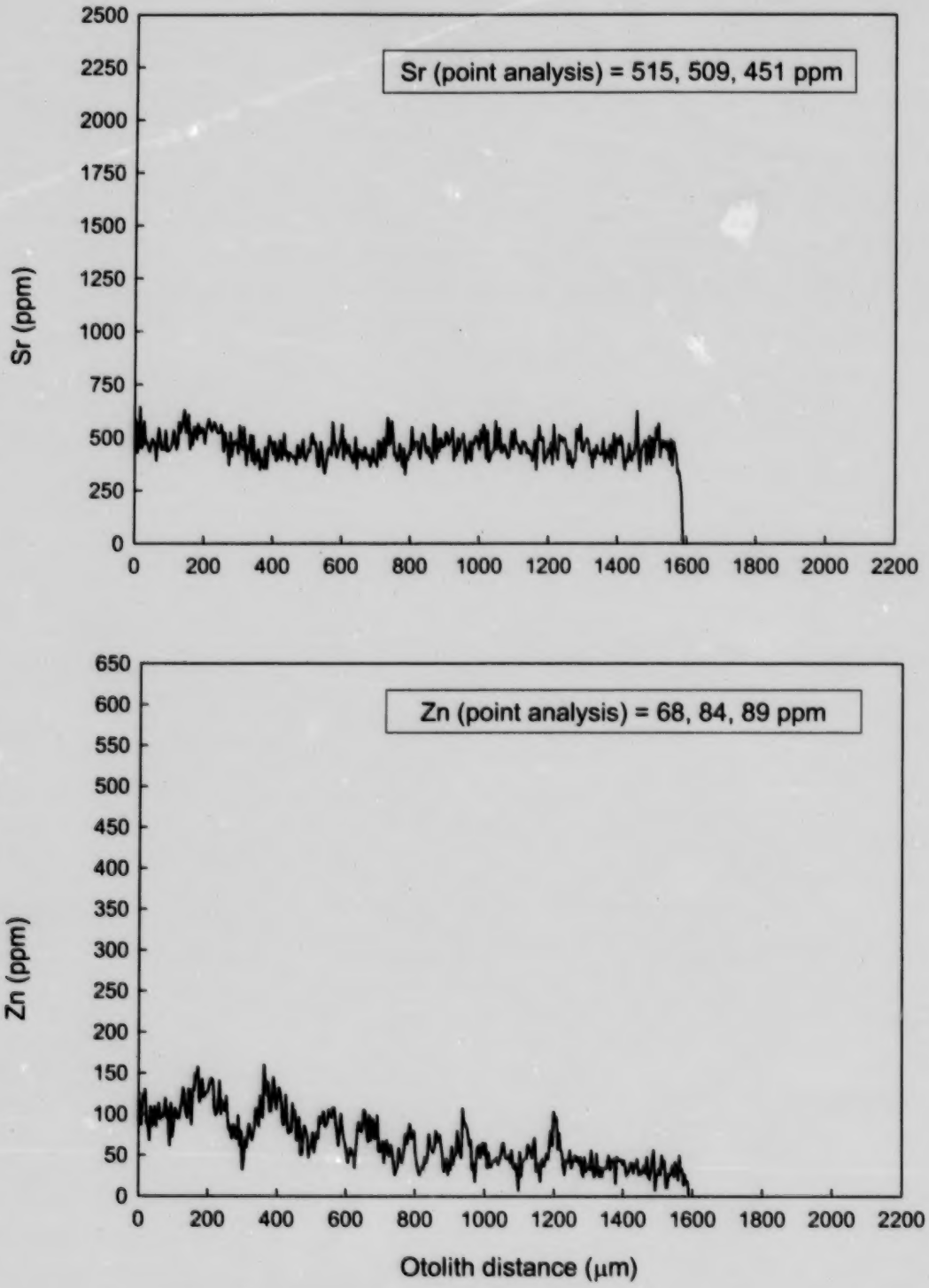

Fig. 5. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (539 mm, 1246 g, male, 20 yr) caught in Lake A, May 1996. Point analysis results are also indicated.

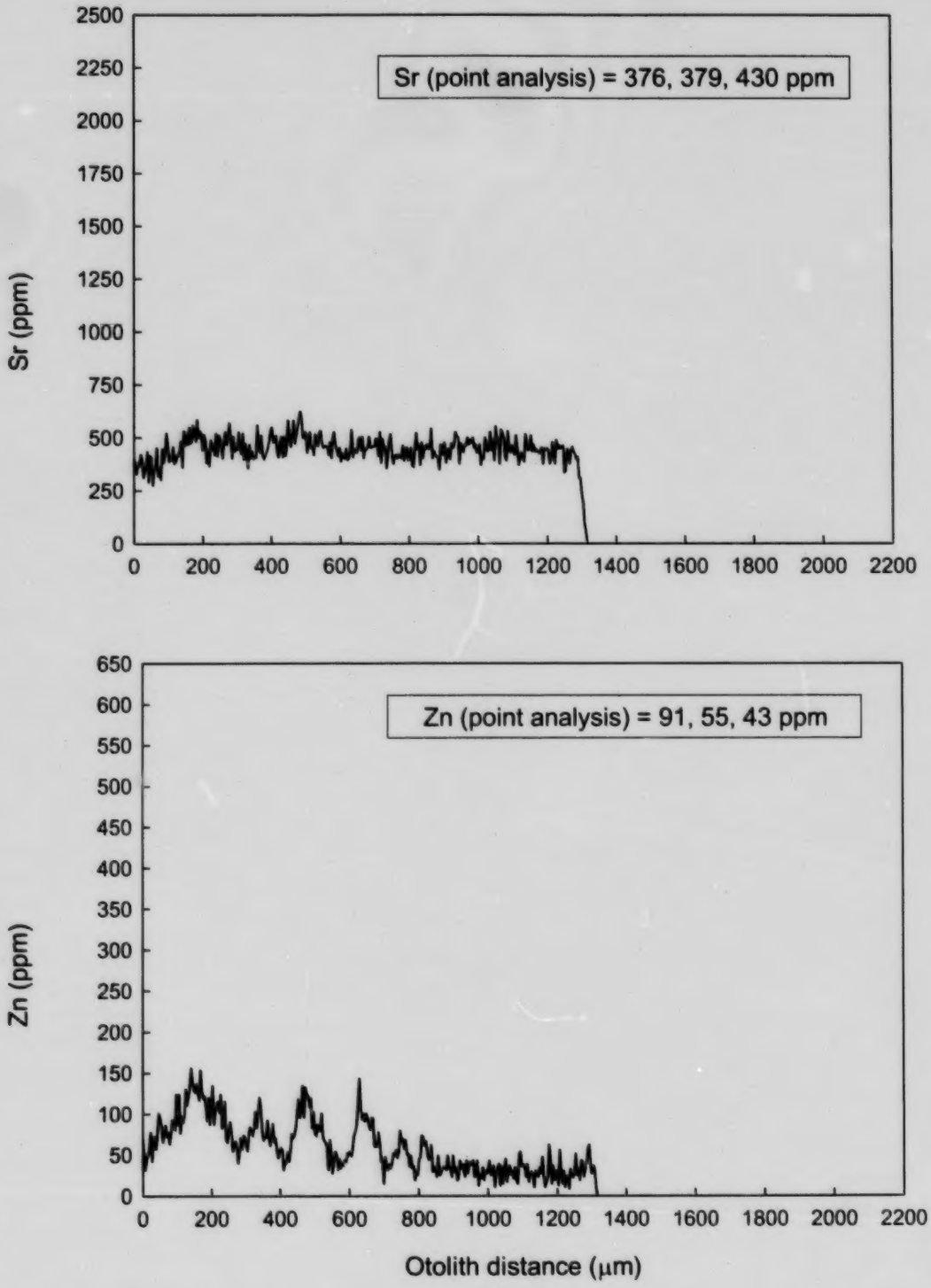

Fig. 6. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (541 mm, 1678 g, male, 17 yr) caught in Lake A, May 1996. Point analysis results are also indicated.

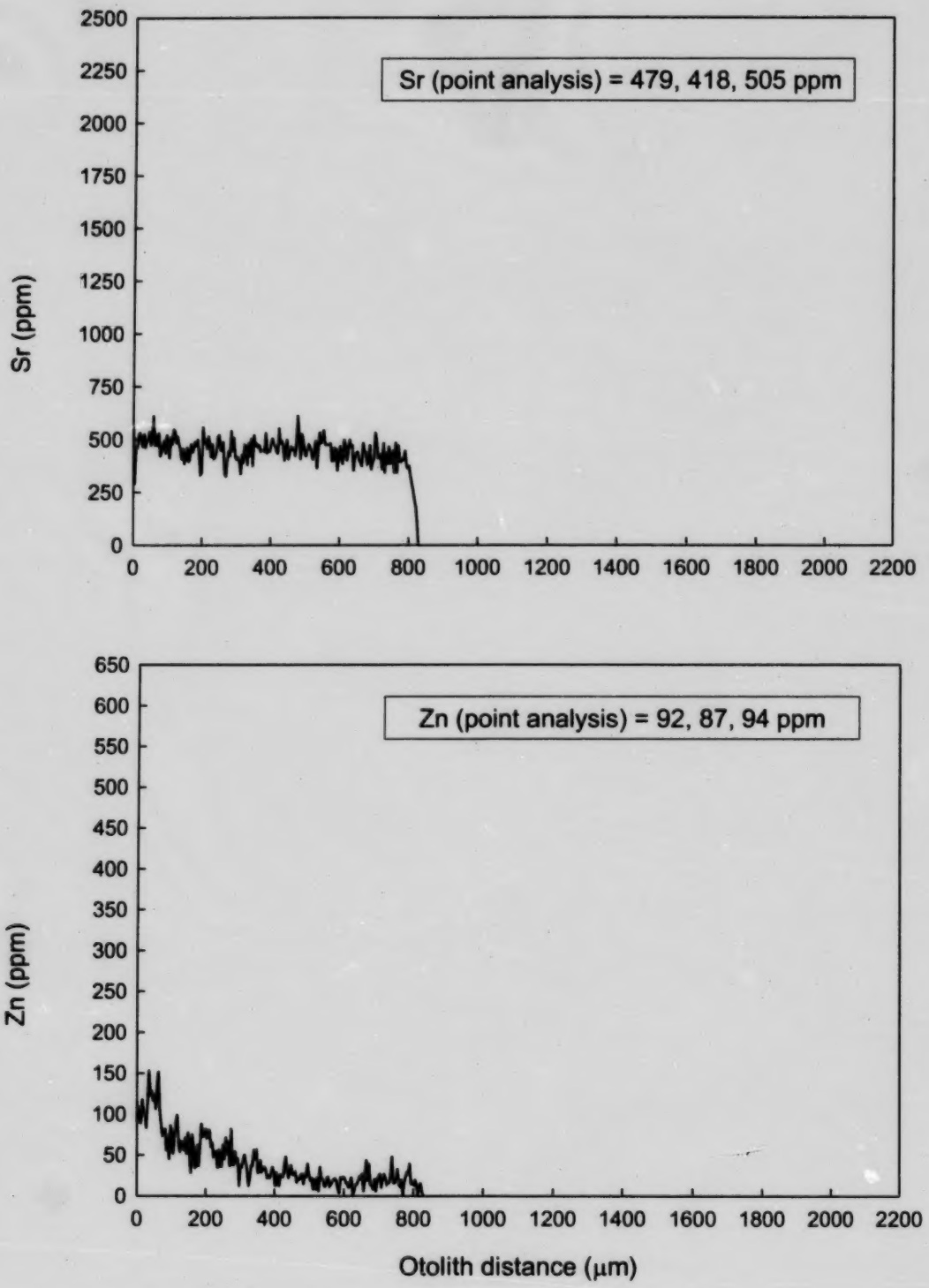

Fig. 7. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (582 mm, 1965 g, male, 17 yr) caught in Lake A, May 1996. Point analysis results are also indicated.

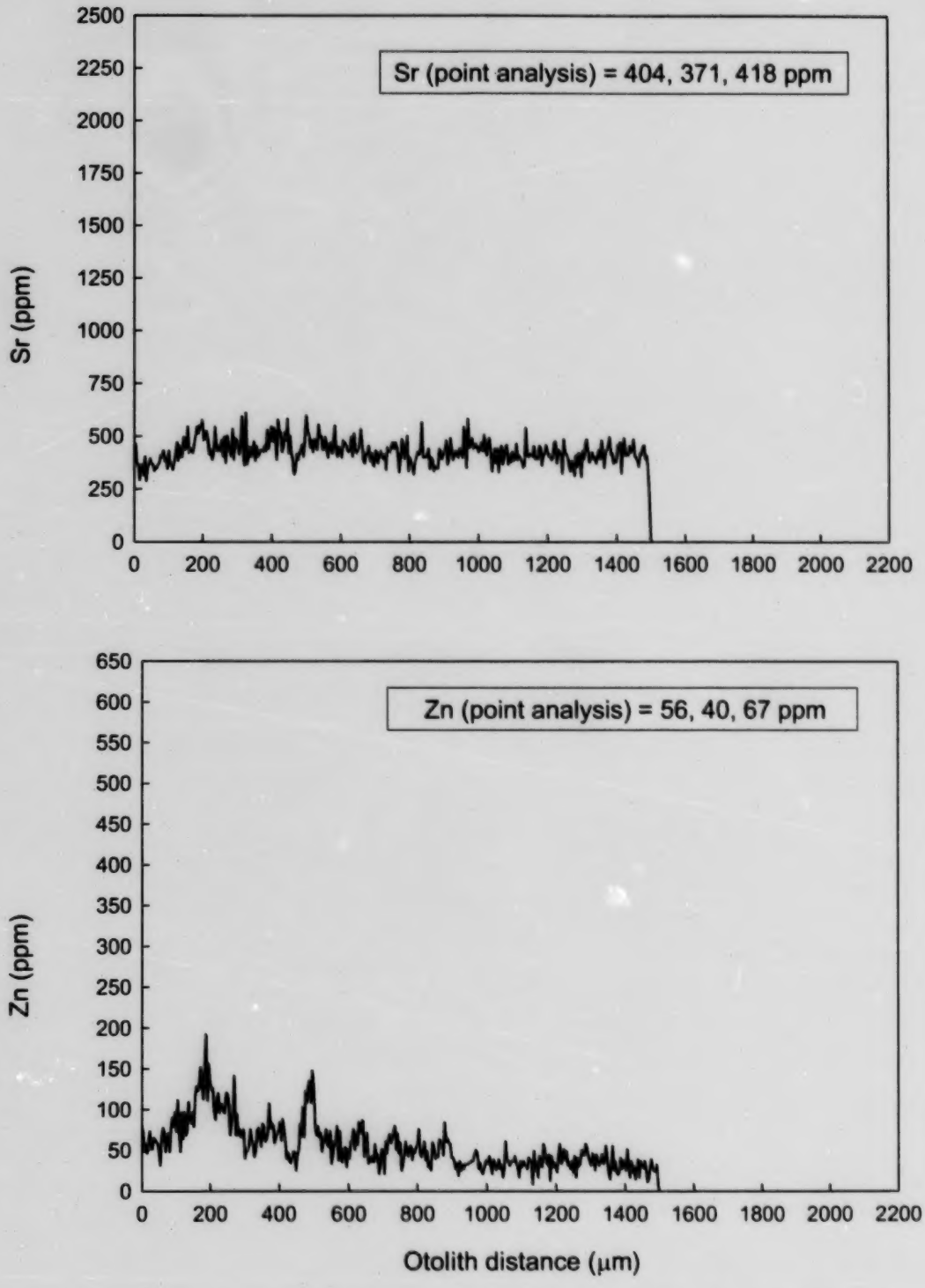

Fig. 8. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (524 mm, 1352 g, female, 20 yr) caught in Lake A, May 1996. Point analysis results are also indicated.

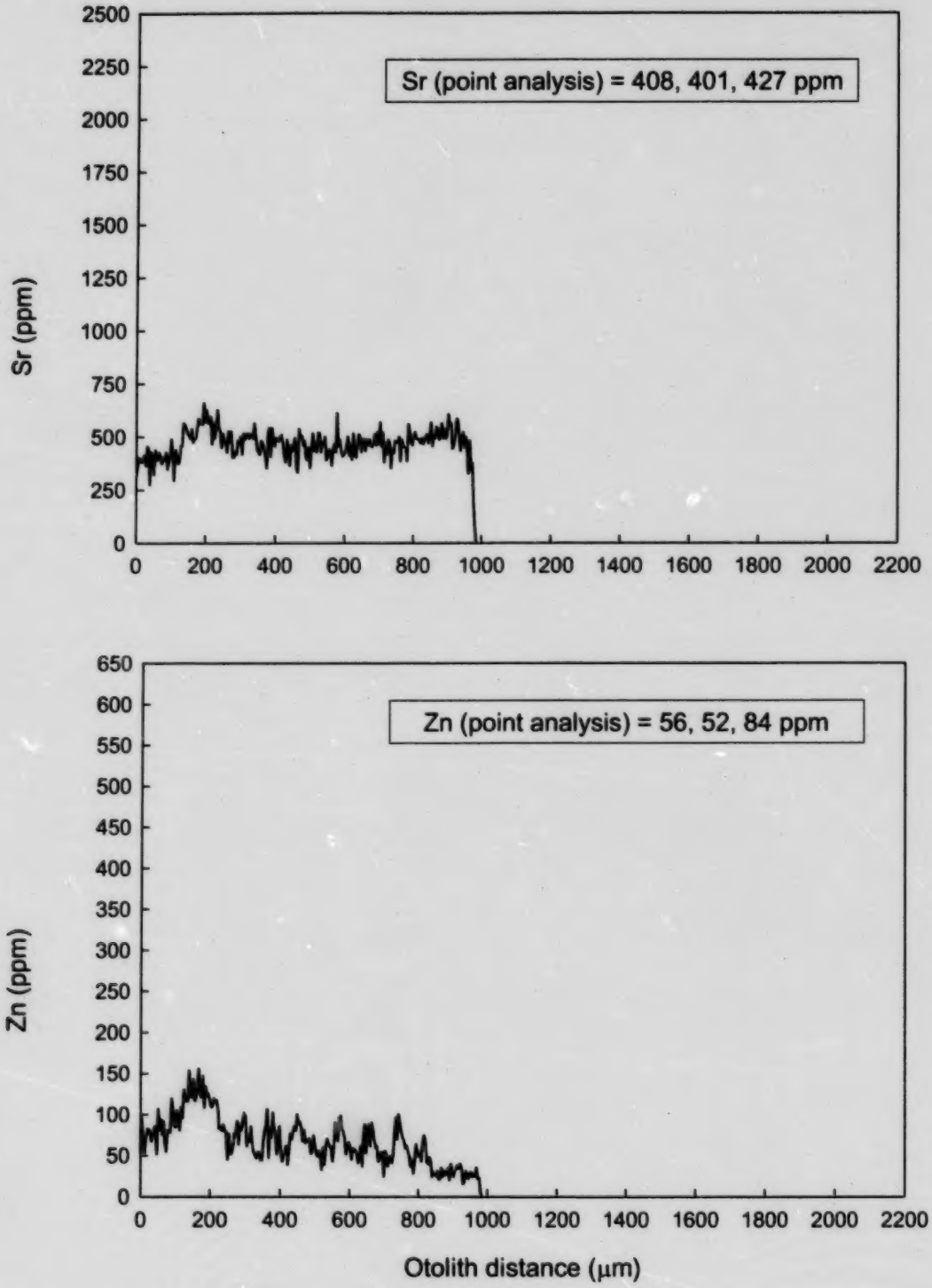

Fig. 9. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (289 mm, 210 g, female, 15 yr) caught in Lake A, May 1990. Point analysis results are also indicated.

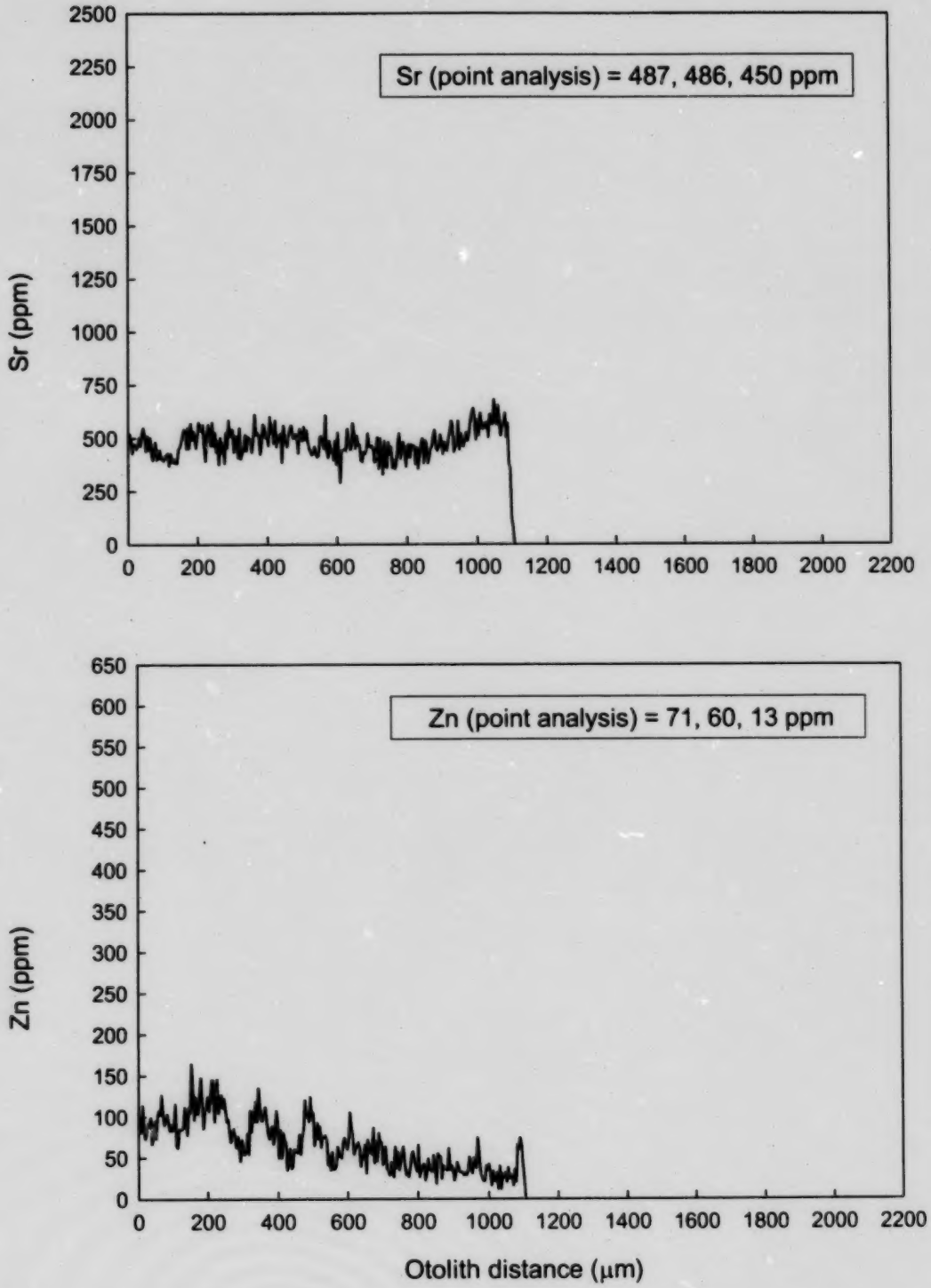

Fig. 10. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (290 mm, 189 g, female, 18 yr) caught in Lake A, May 1996. Point analysis results are also indicated.

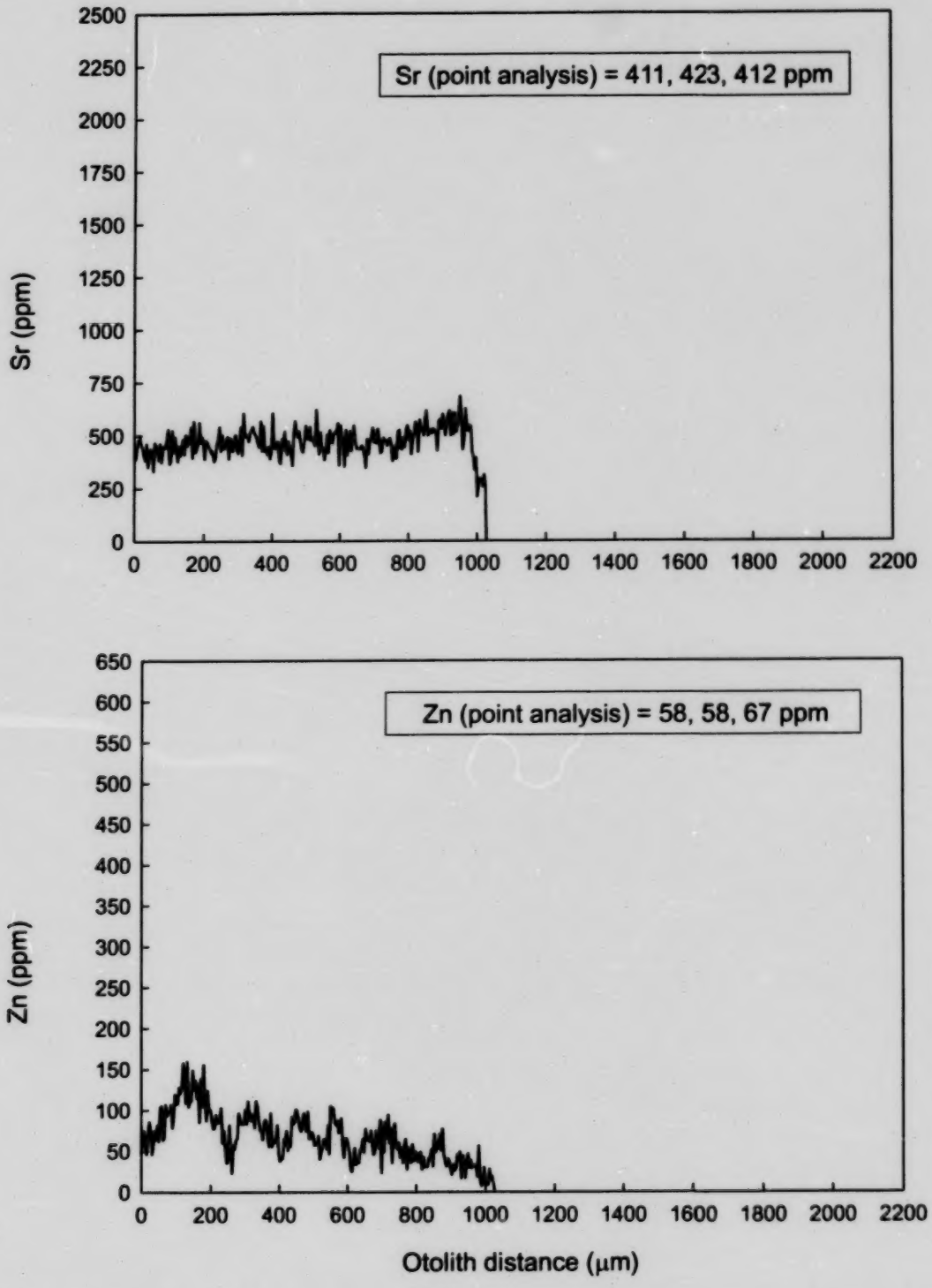

Fig. 11. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (259 mm, 163 g, female, 10 yr) caught in Lake A, May 1996. Point analysis results are also indicated.

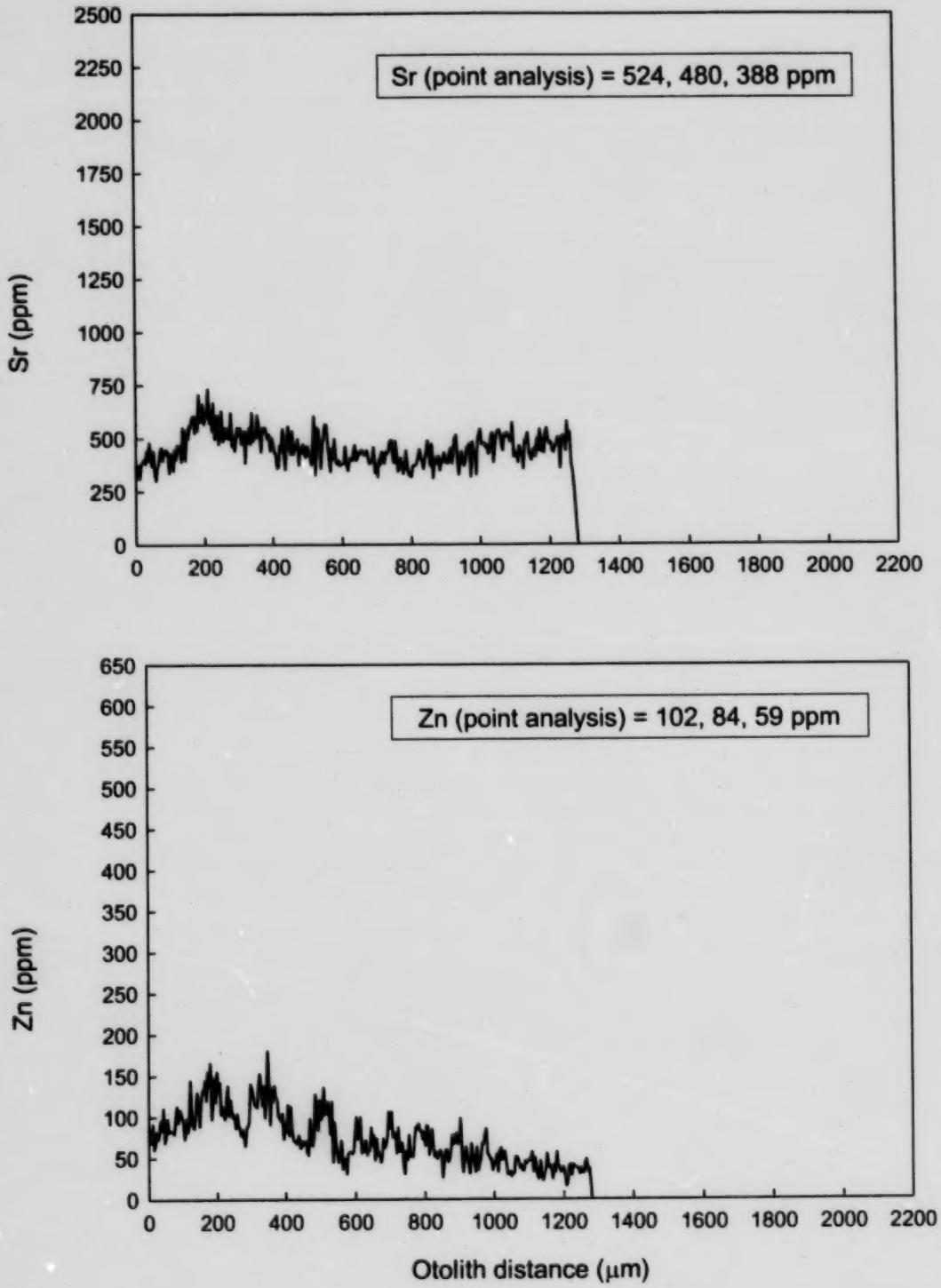

Fig. 12. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (286 mm, 171 g, male, 16 yr) caught in Lake A, May 1996. Point analysis results are also indicated.

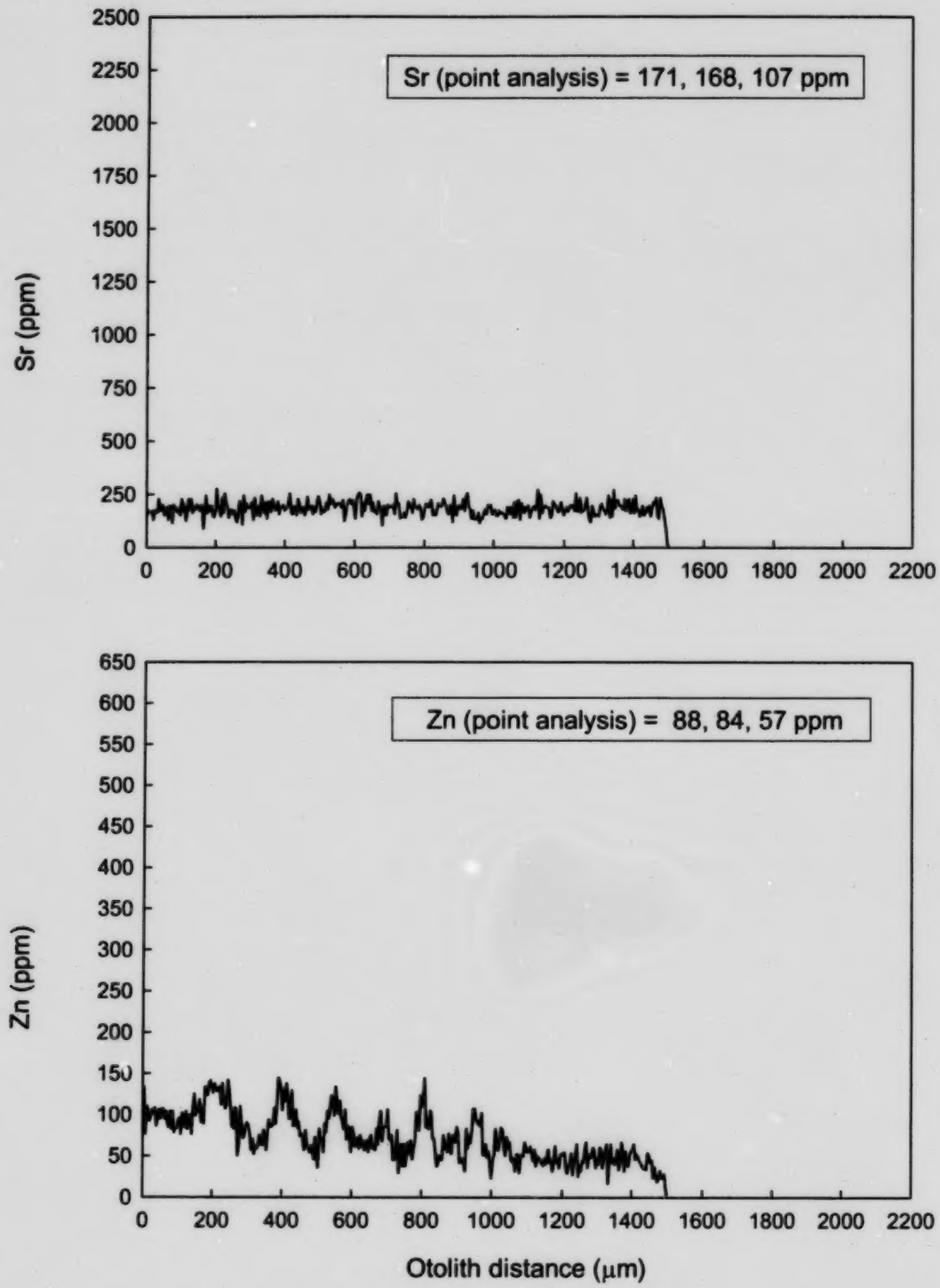

Fig. 13. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (366 mm, 869 g, female, 19 yr) caught in Alexandra Lake, May 1995. Point analysis results are also indicated.

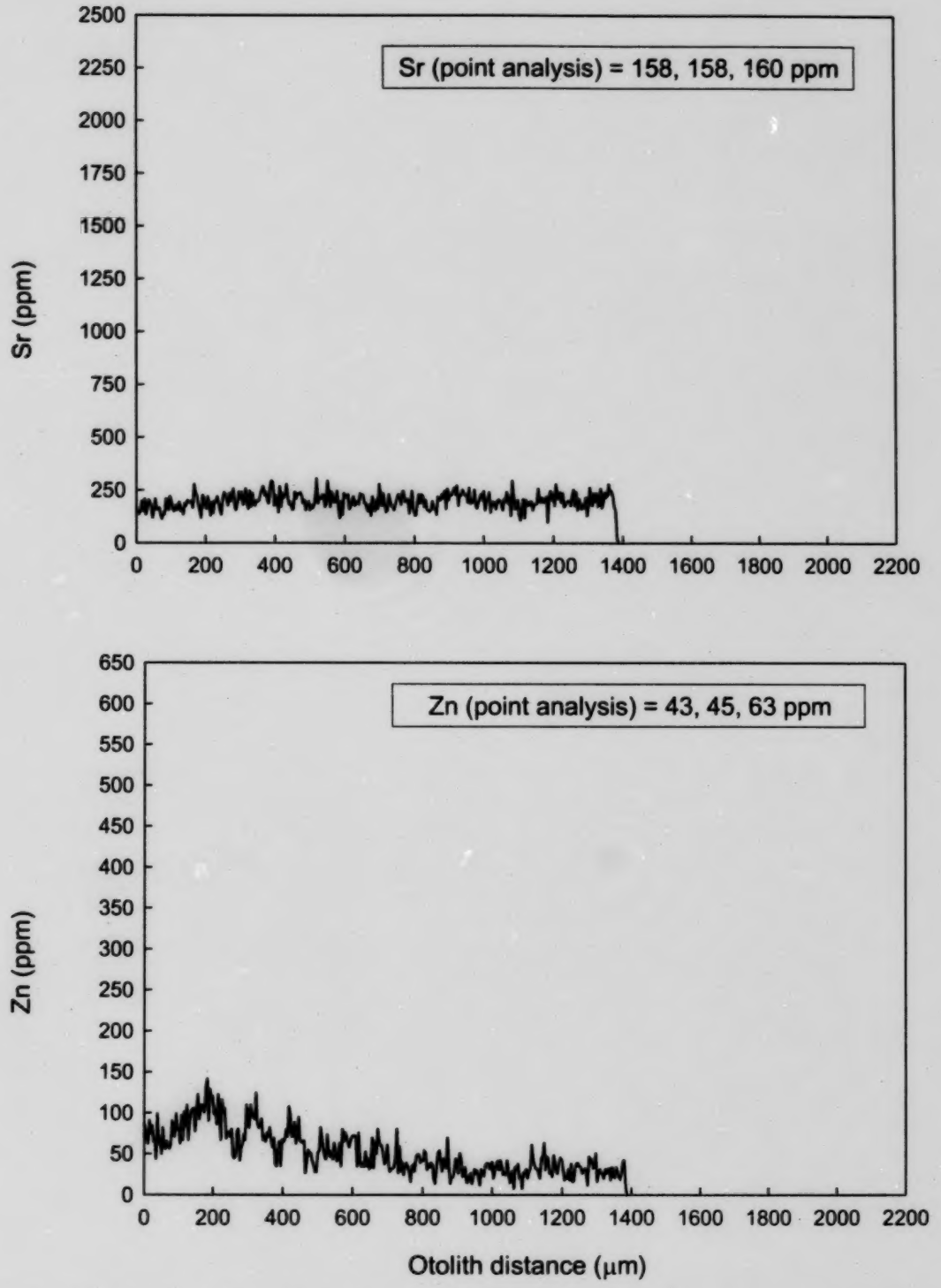

Fig. 14. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (310 mm, 618 g, male, 21 yr) caught in Alexandra Lake, May 1995. Point analysis results are also indicated.

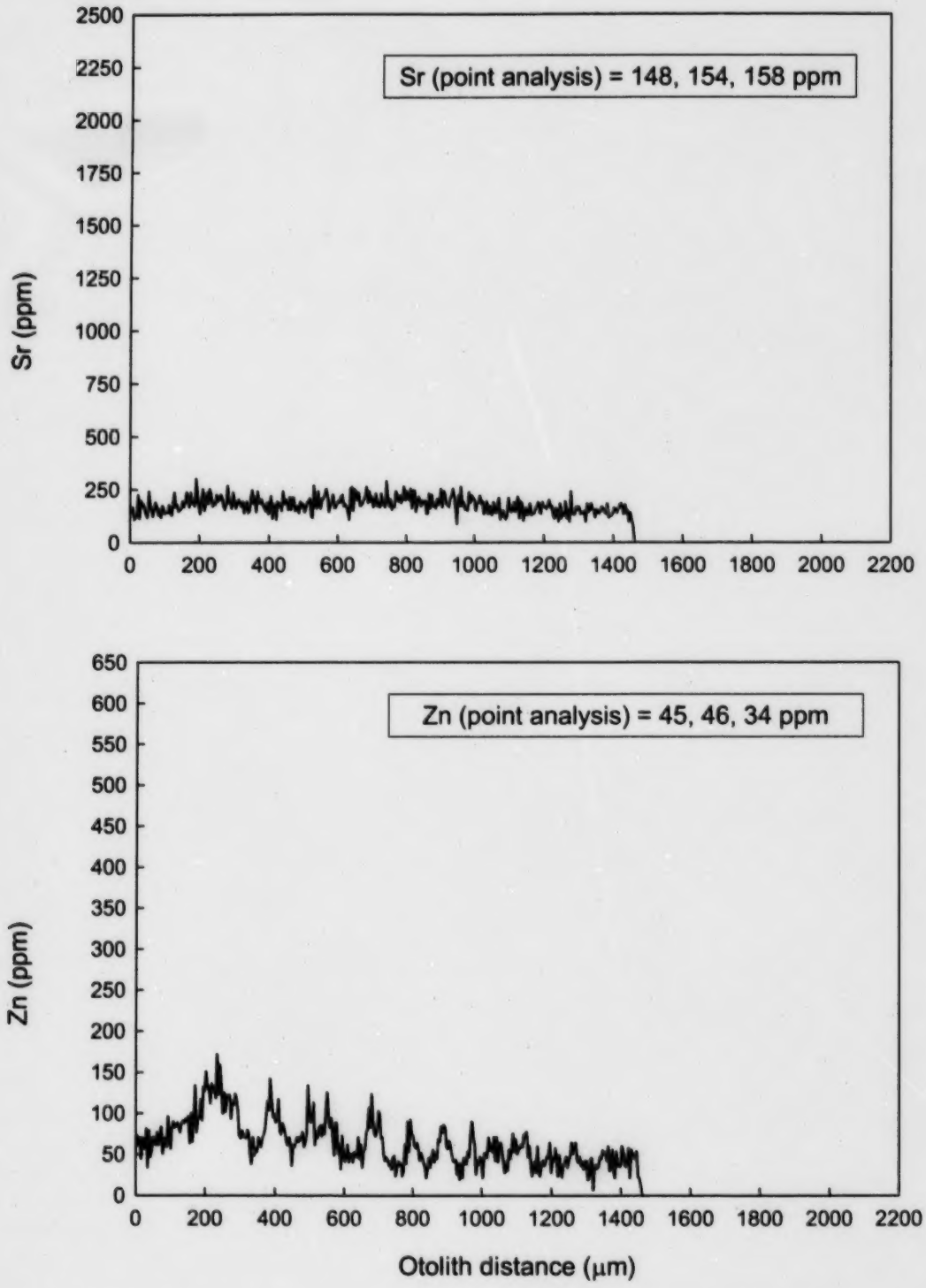

Fig. 15. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (519 mm, 3242 g, female, 14 yr) caught in Alexandra Lake, May 1995. Point analysis results are also indicated.

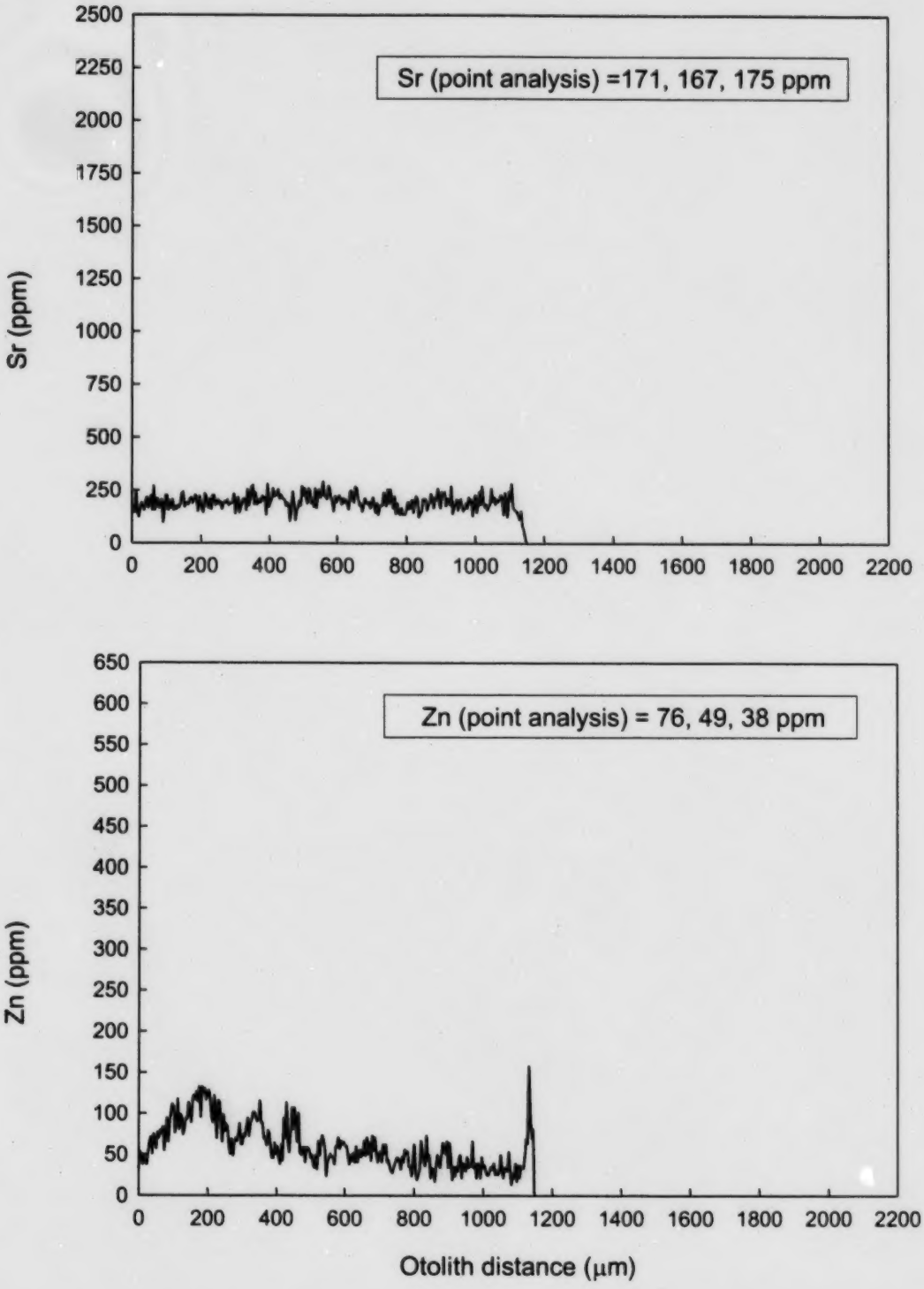

Fig. 16. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (201 mm, 156 g, male, 18 yr) caught in Alexandra Lake, May 1995. Point analysis results are also indicated.

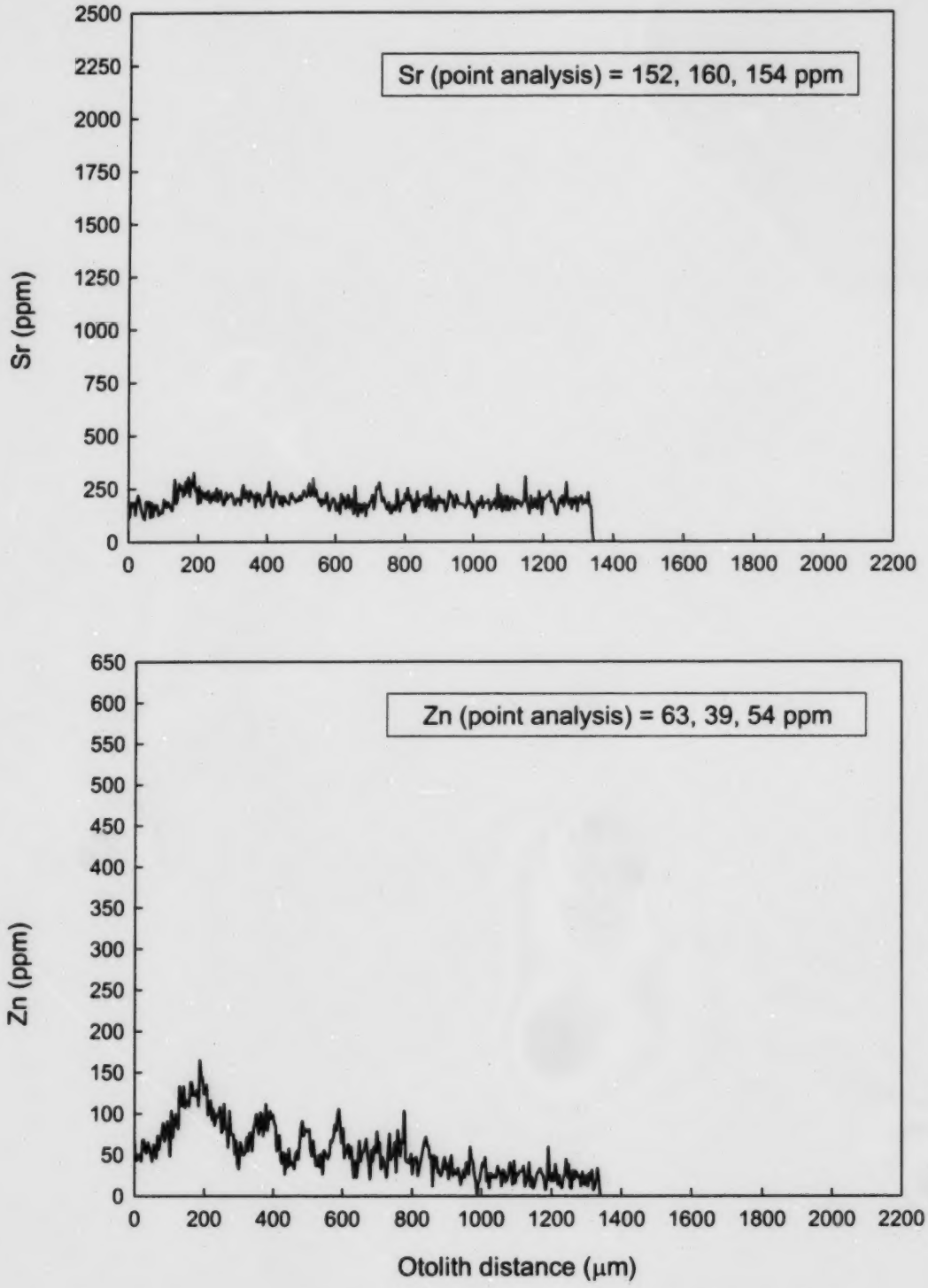

Fig. 17. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (222 mm, 184 g, male, 19 yr) caught in Alexandra Lake, May 1995. Point analysis results are also indicated.

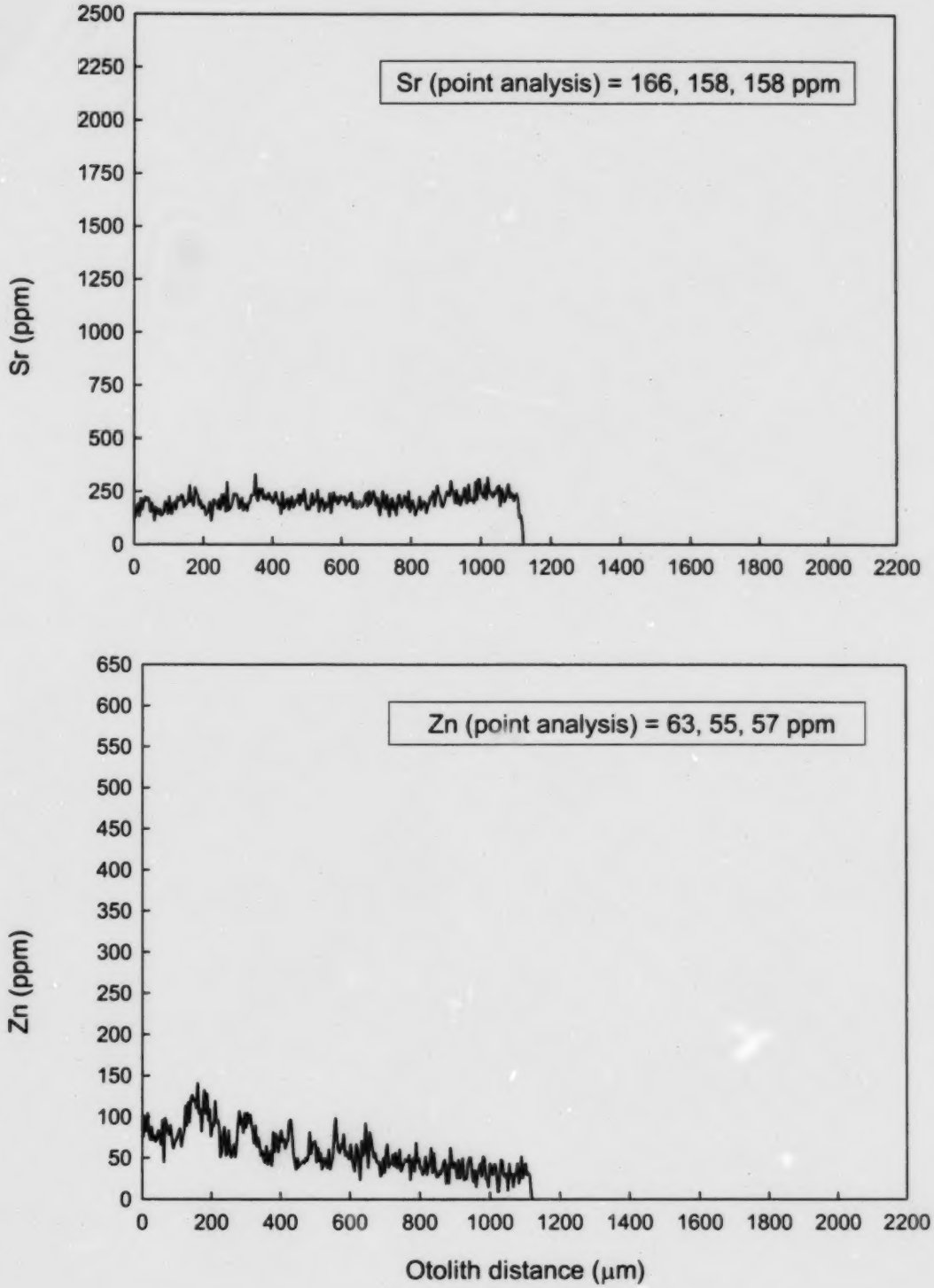

Fig. 18. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (177 mm, 101 g, female, 18 yr) caught in Alexandra Lake, May 1995. Point analysis results are also indicated.

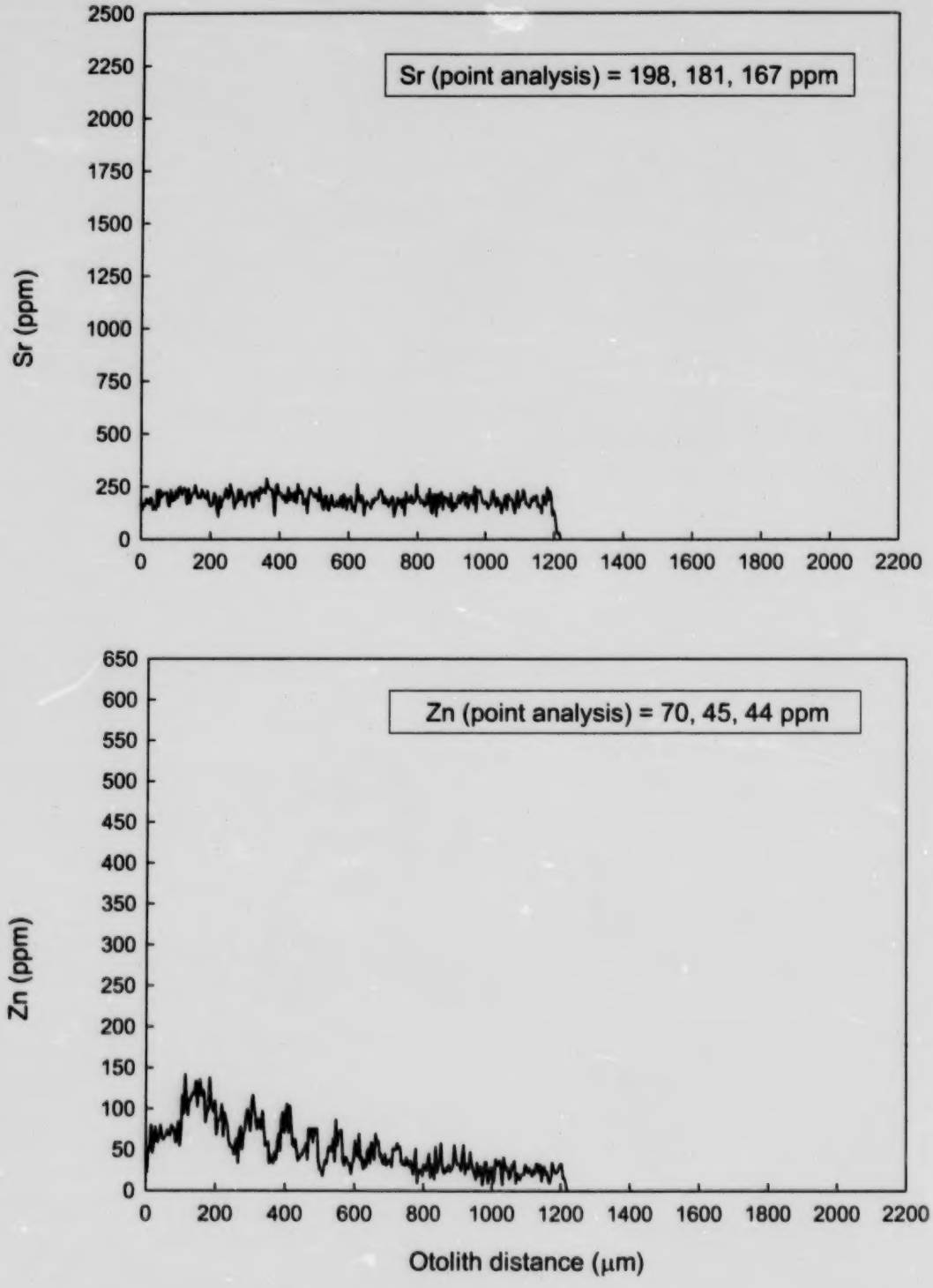

Fig. 19. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (220 mm, 100 g, male, 21 yr) caught in Alexandra Lake, May 1995. Point analysis results are also indicated.

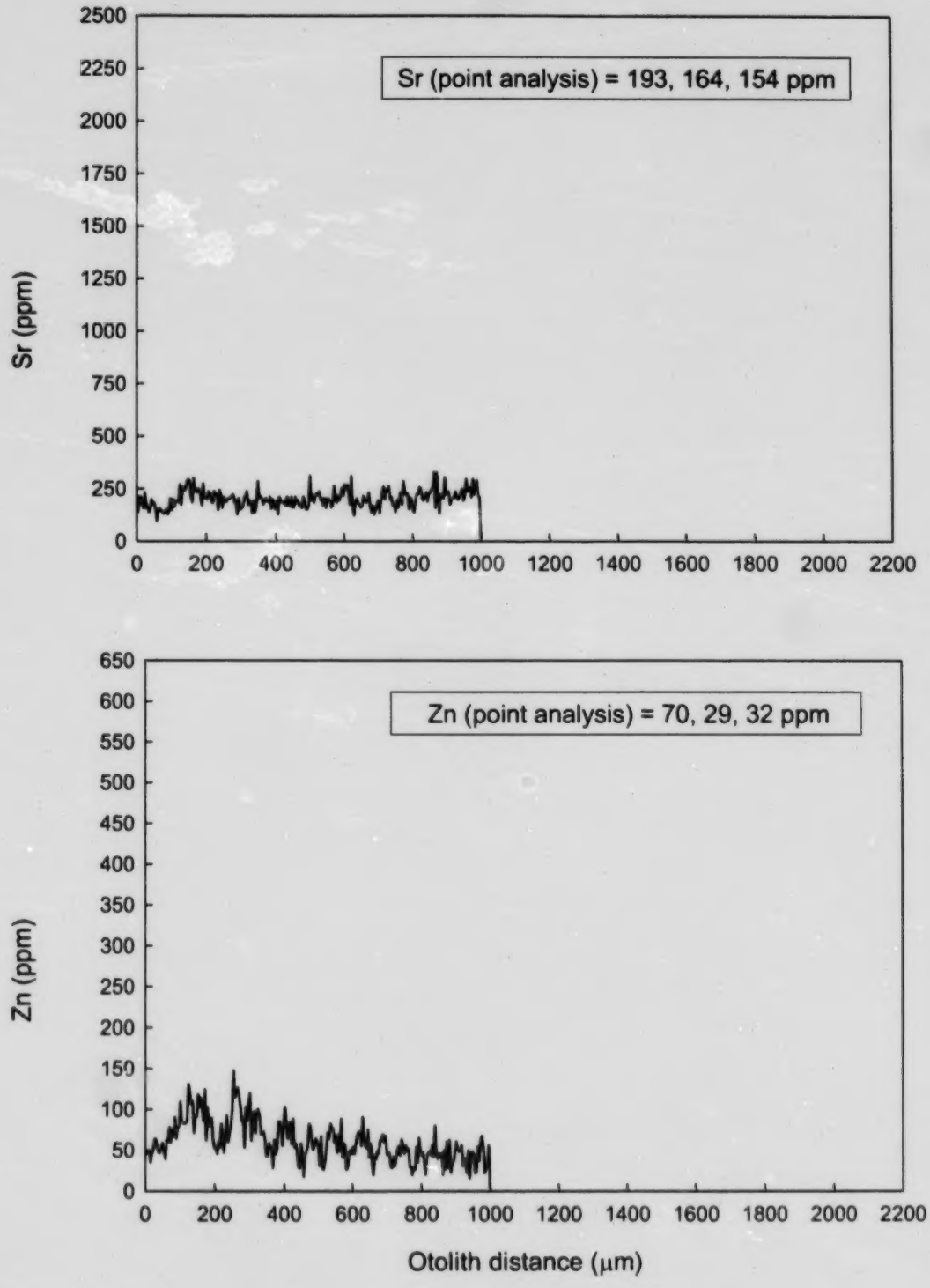

Fig. 20. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (219 mm, 87 g, female, 14 yr) caught in Alexandra Lake, May 1995. Point analysis results are also indicated.

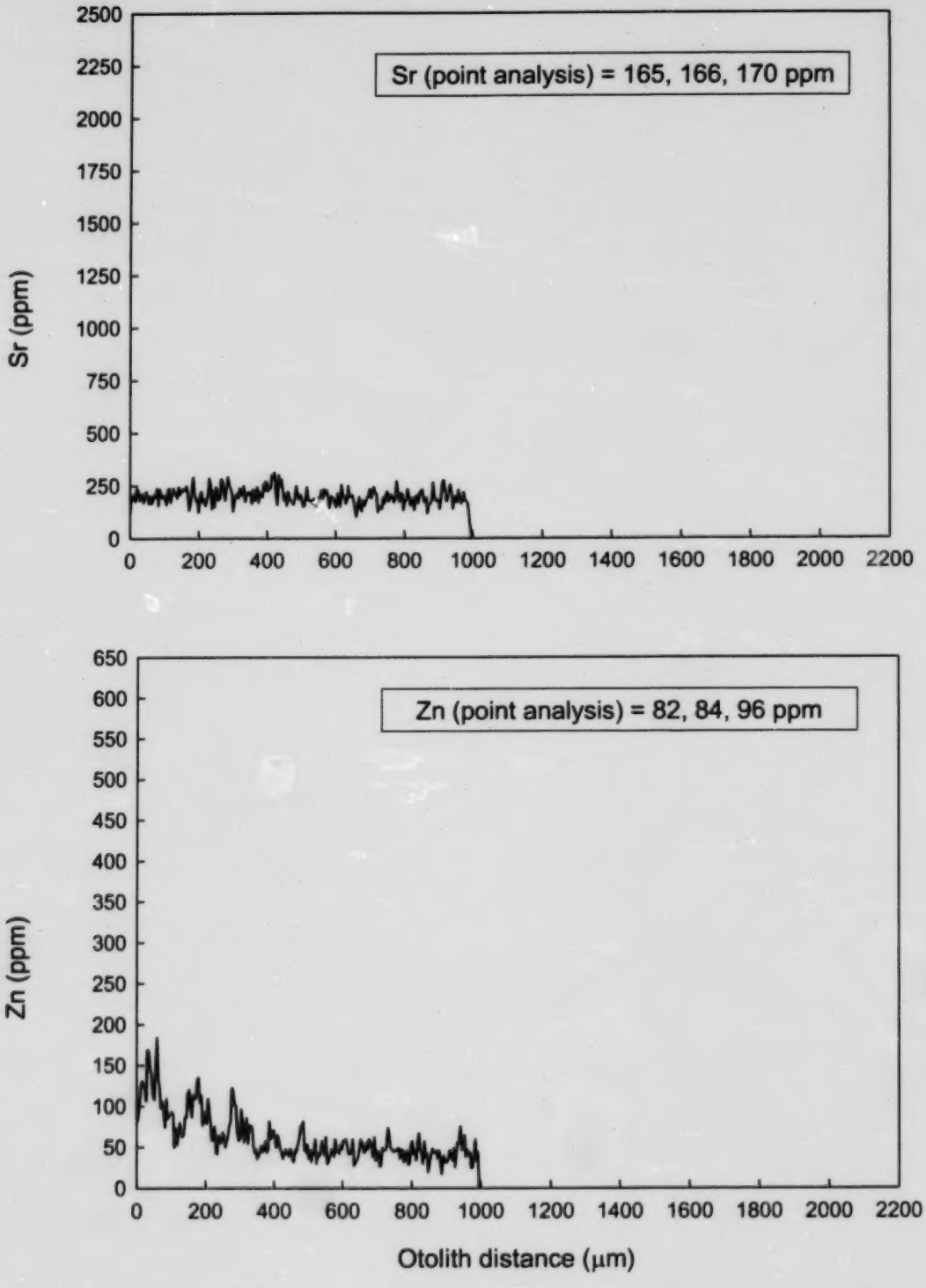

Fig. 21. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (262 mm, 150 g, female, 13 yr) caught in Alexandra Lake, May 1995. Point analysis results are also indicated.

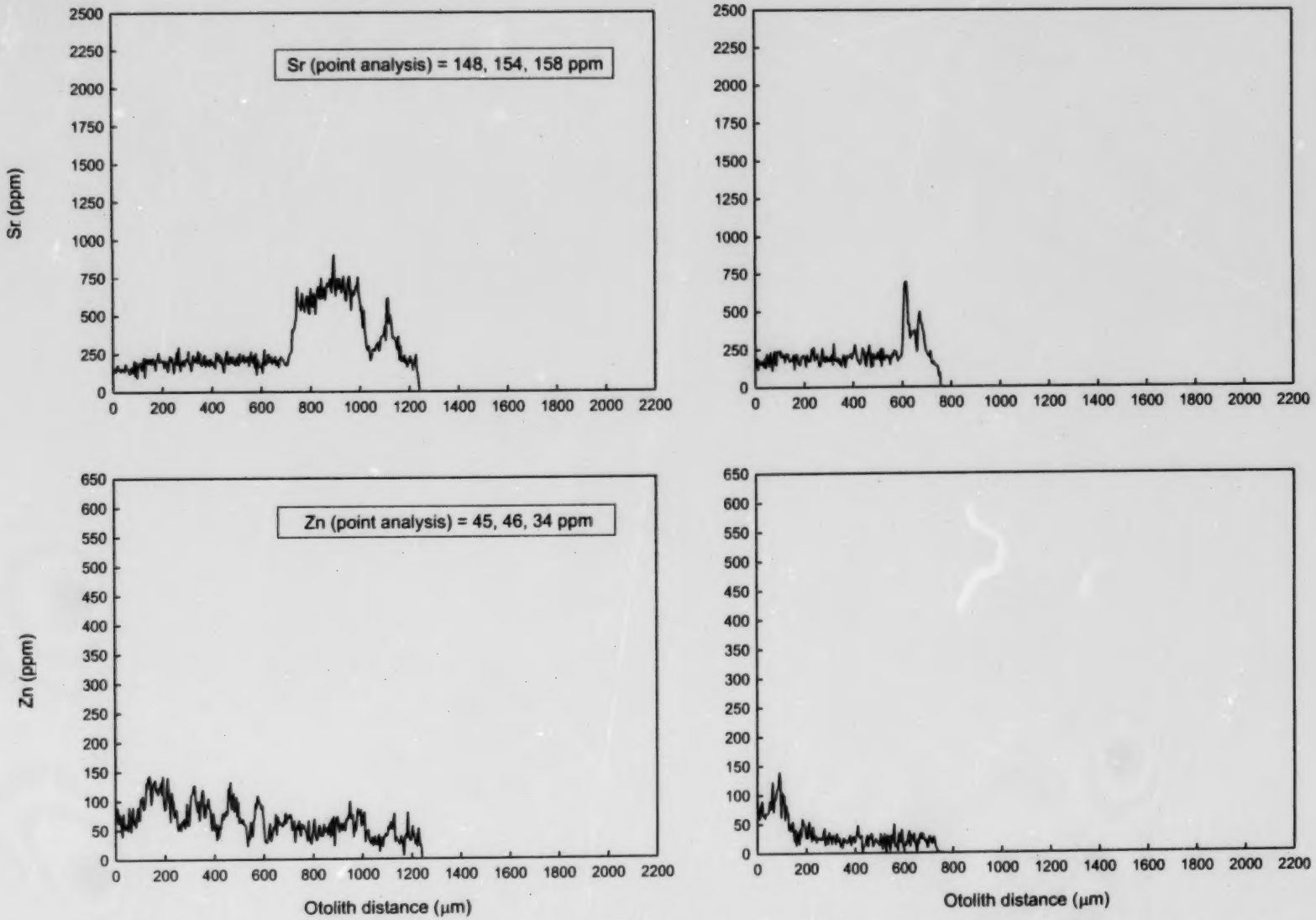

Fig. 22. Strontium (top) and zinc (bottom) profiles from two scanning proton microprobe line-scans of an otolith from an Arctic char (519 mm, 3242 g, female, 14 yr) caught in Alexandra Lake, May 1995. Point analysis was conducted in conjunction with one of the line-scans and the results are indicated.

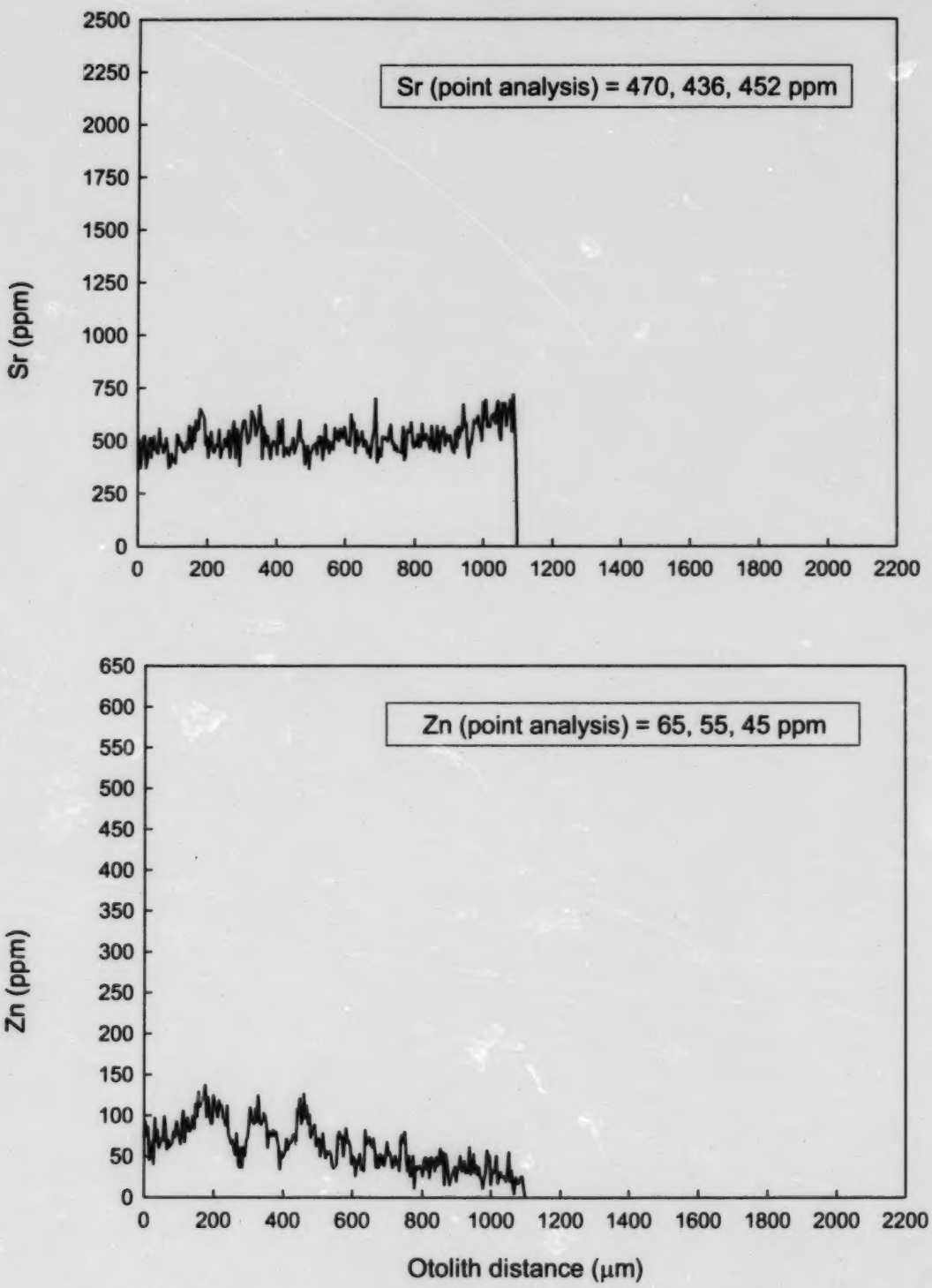

Fig. 23. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (257 mm, 119 g, female, 14 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

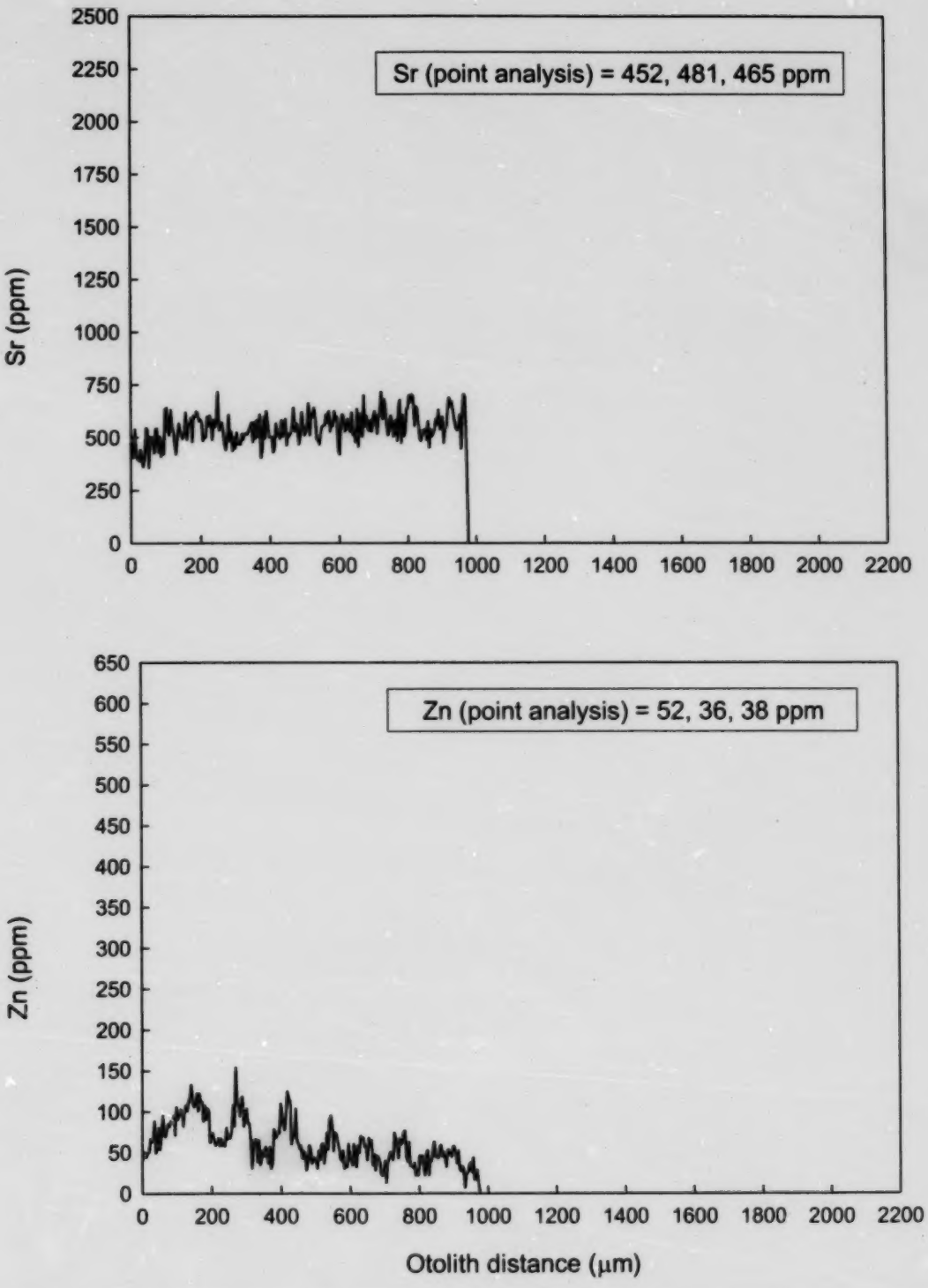

Fig. 24. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (245 mm, 131 g, female, 10 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

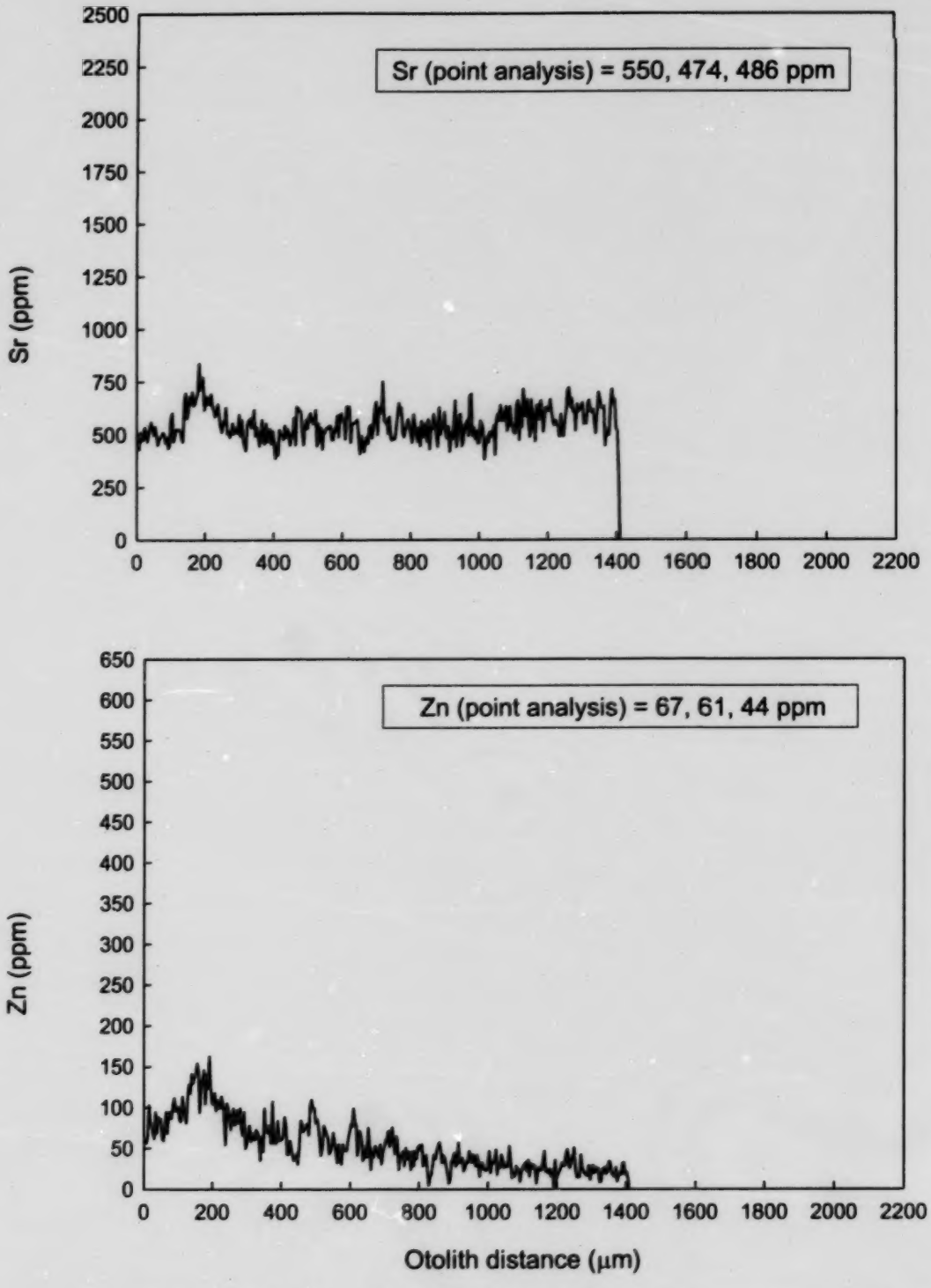

Fig. 25. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (480 mm, 916 g, male, 26 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

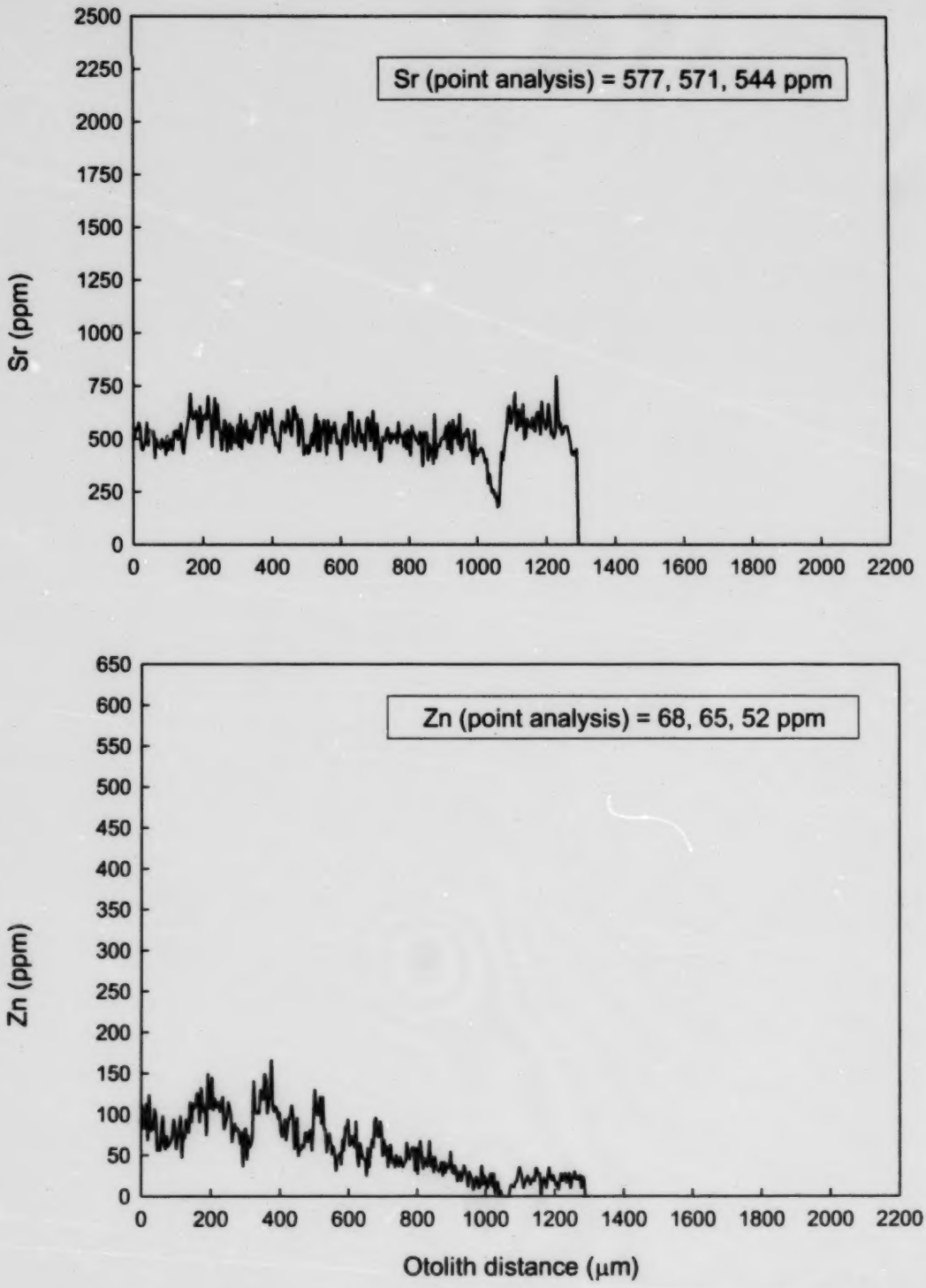

Fig. 26. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (376 mm, 348 g, male, 27 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

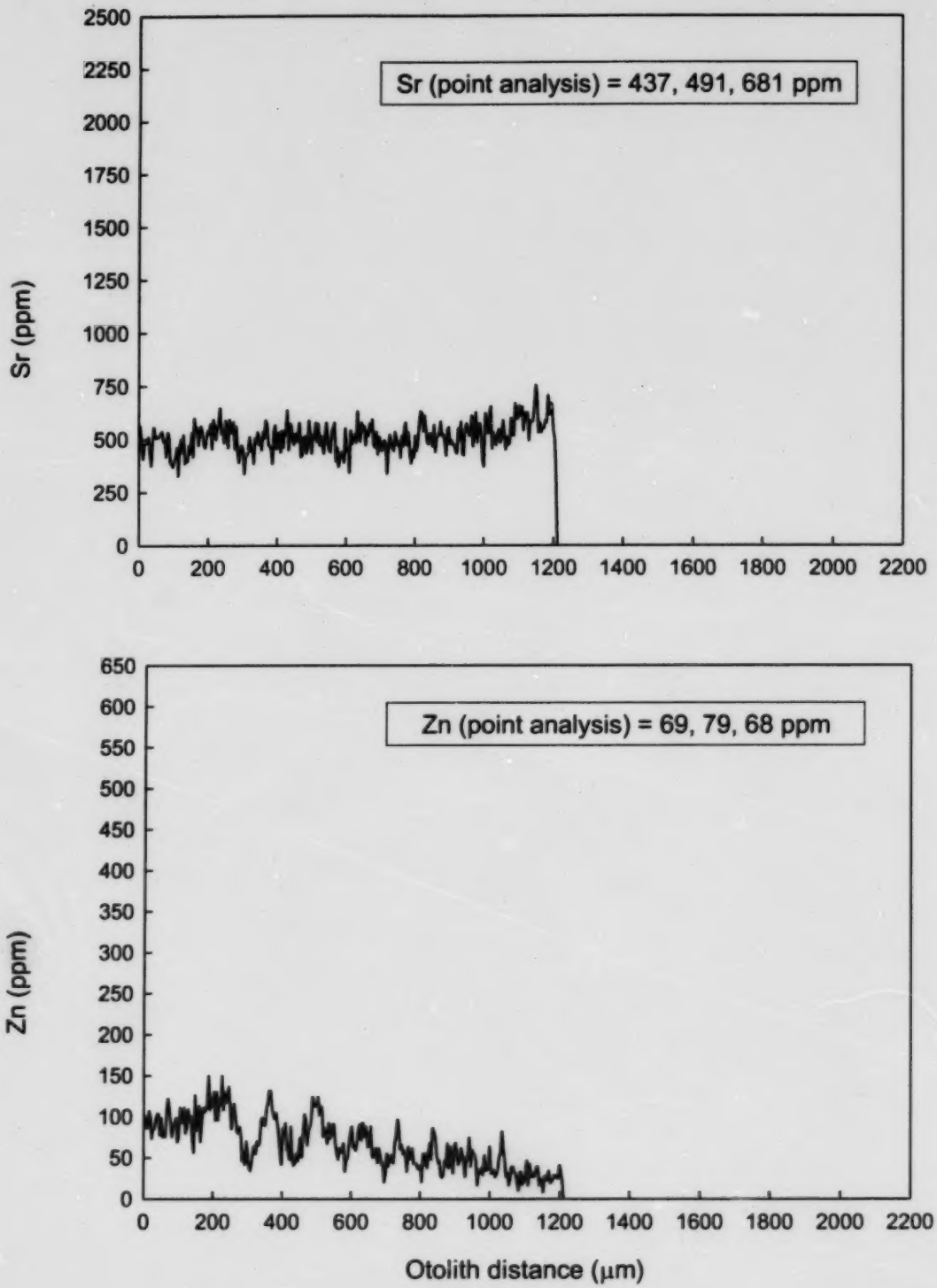

Fig. 27. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (262 mm, 123 g, female, 19 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

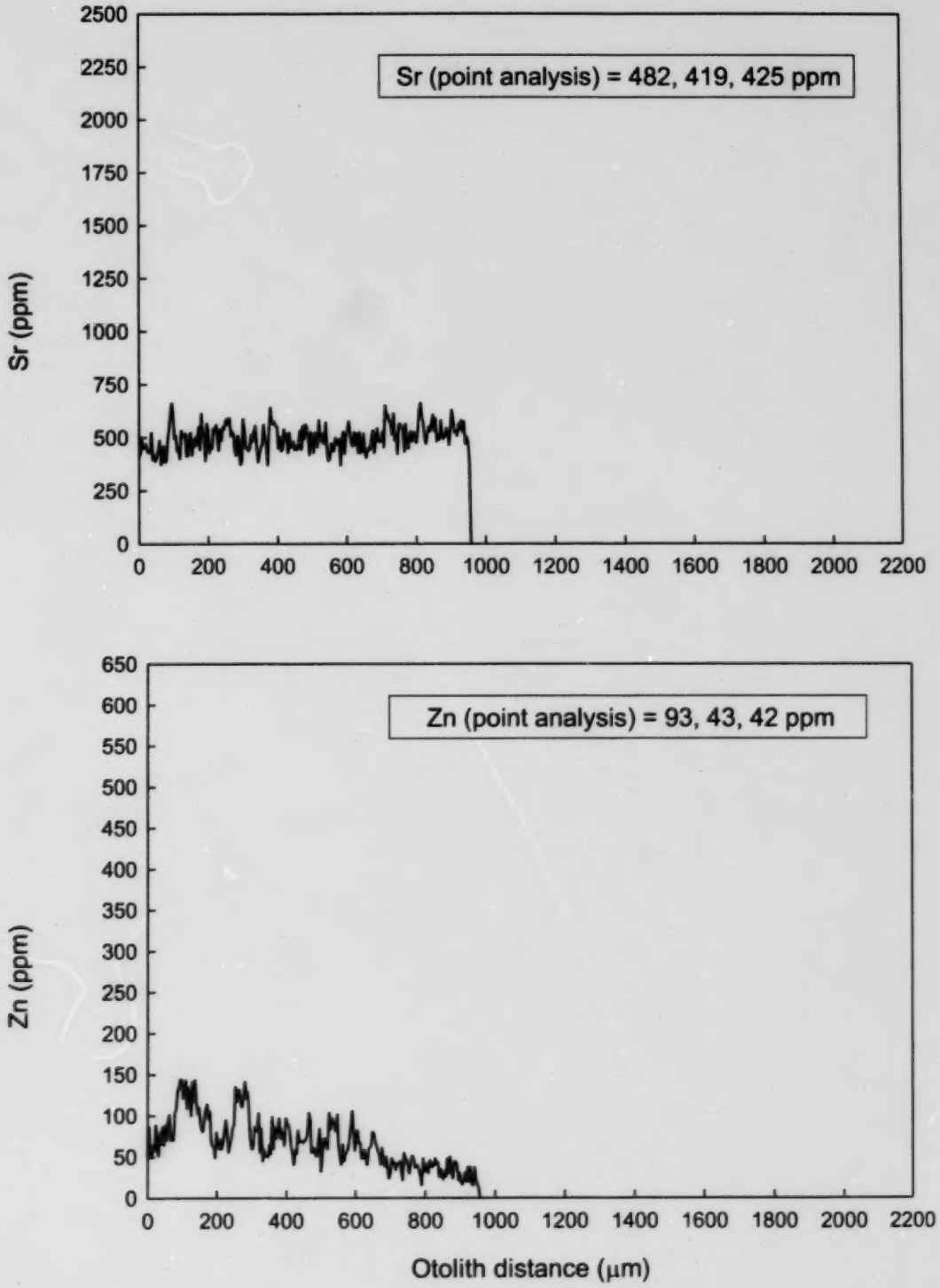

Fig. 28. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (257 mm, 137 g, female, 15 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

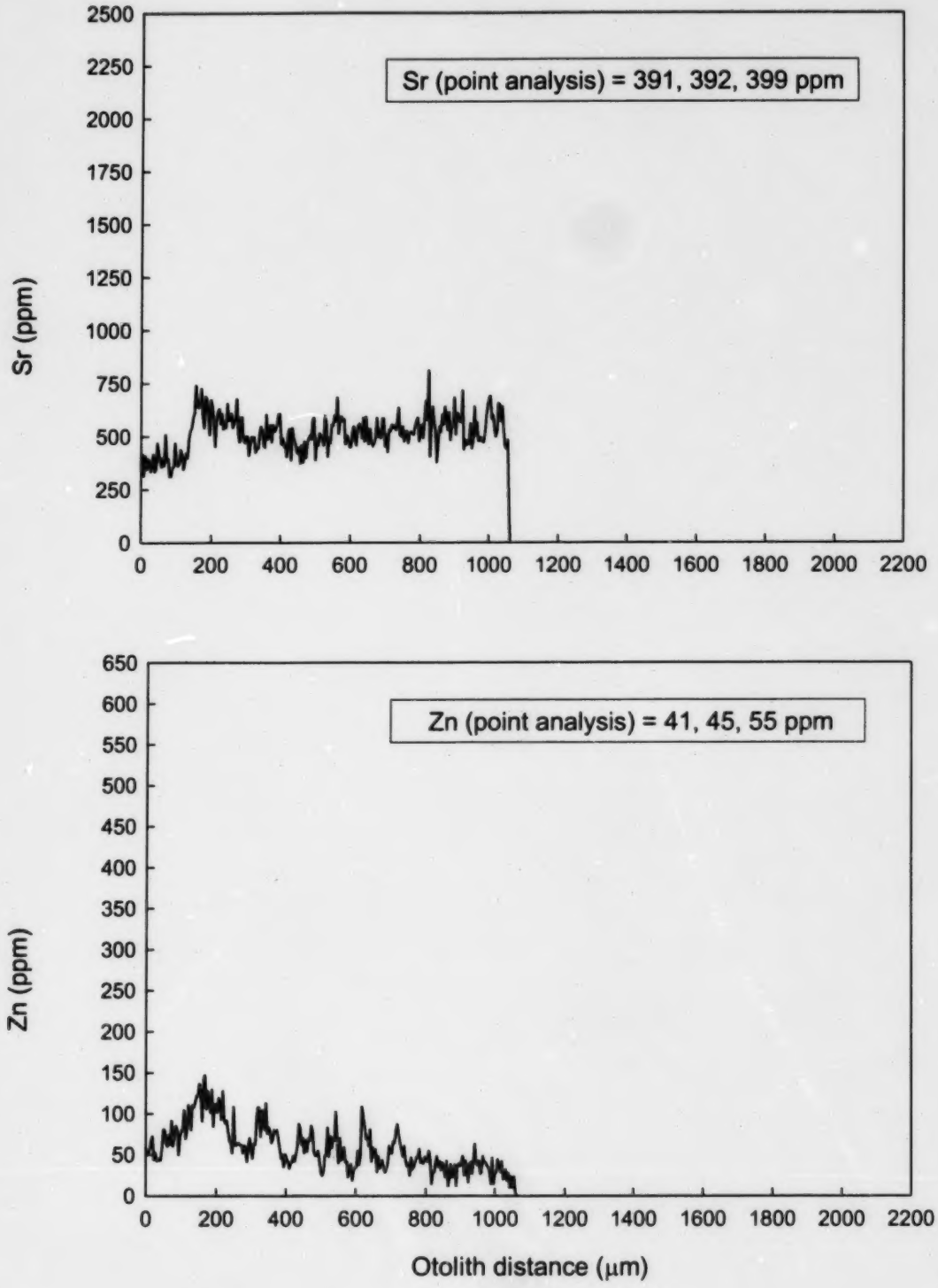

Fig. 29. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (269 mm, 169 g, male, 14 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

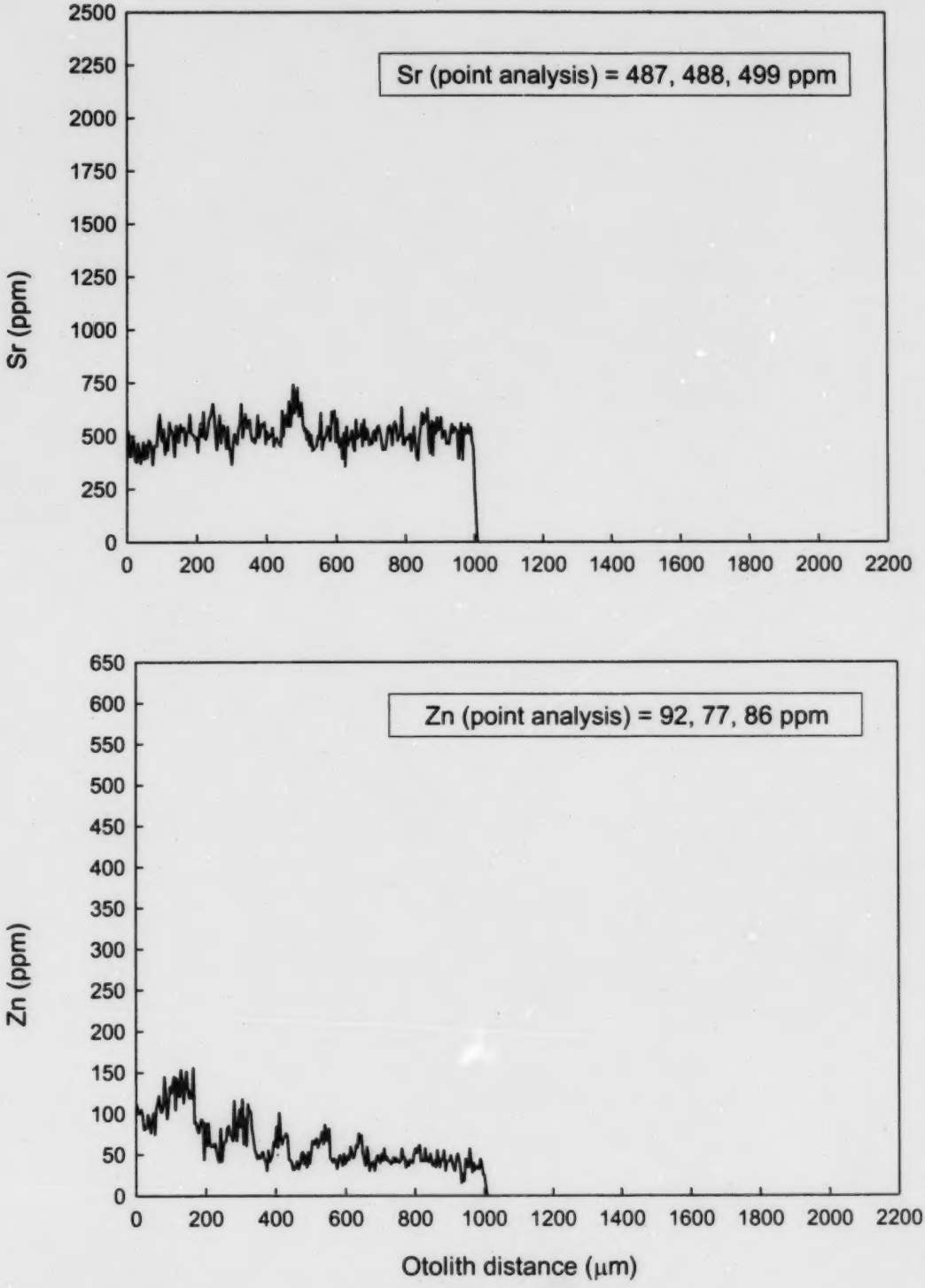

Fig. 30. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (244 mm, 121 g, female, 11 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

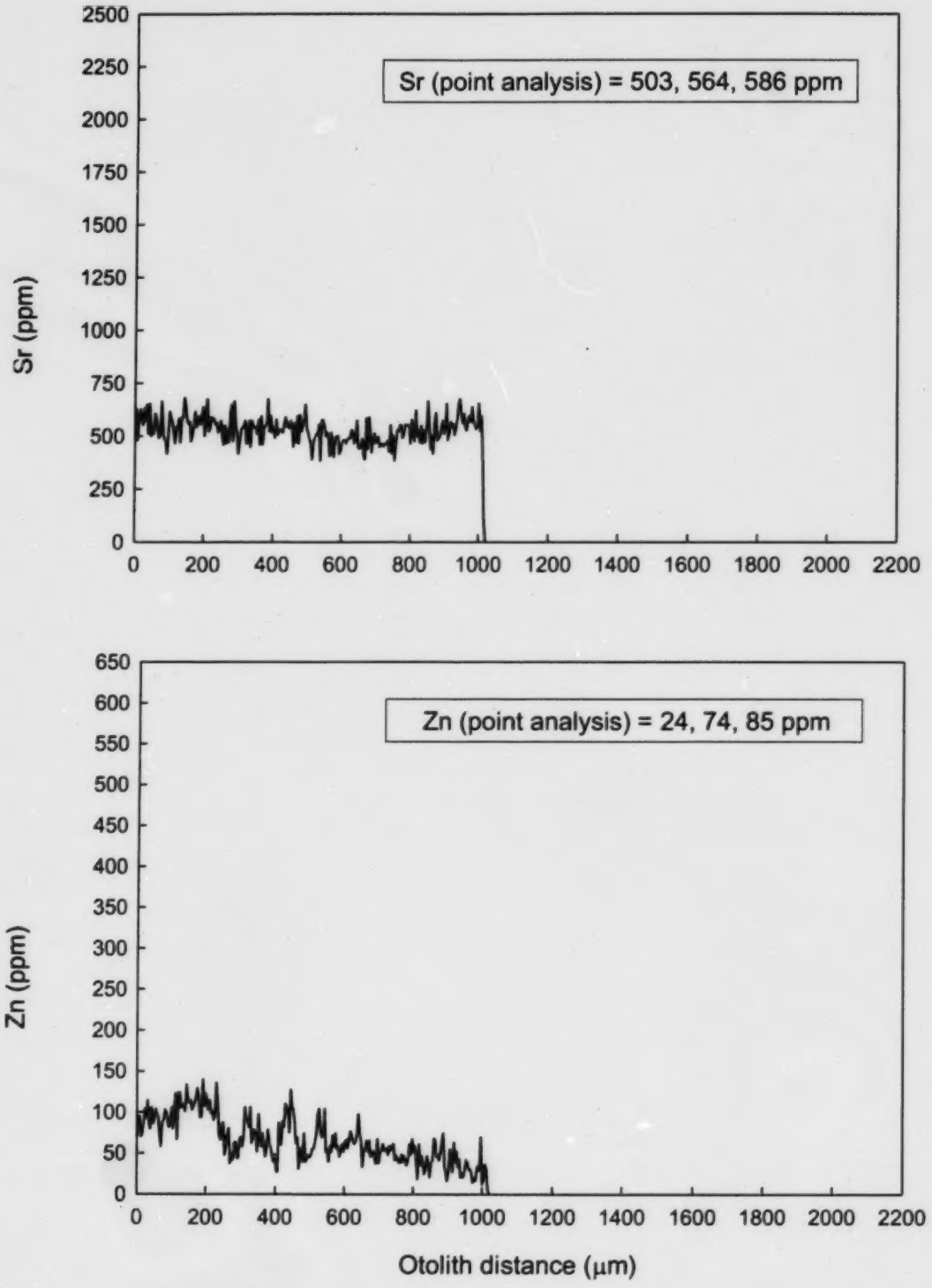

Fig. 31. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (247 mm, 143 g, male, 11 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

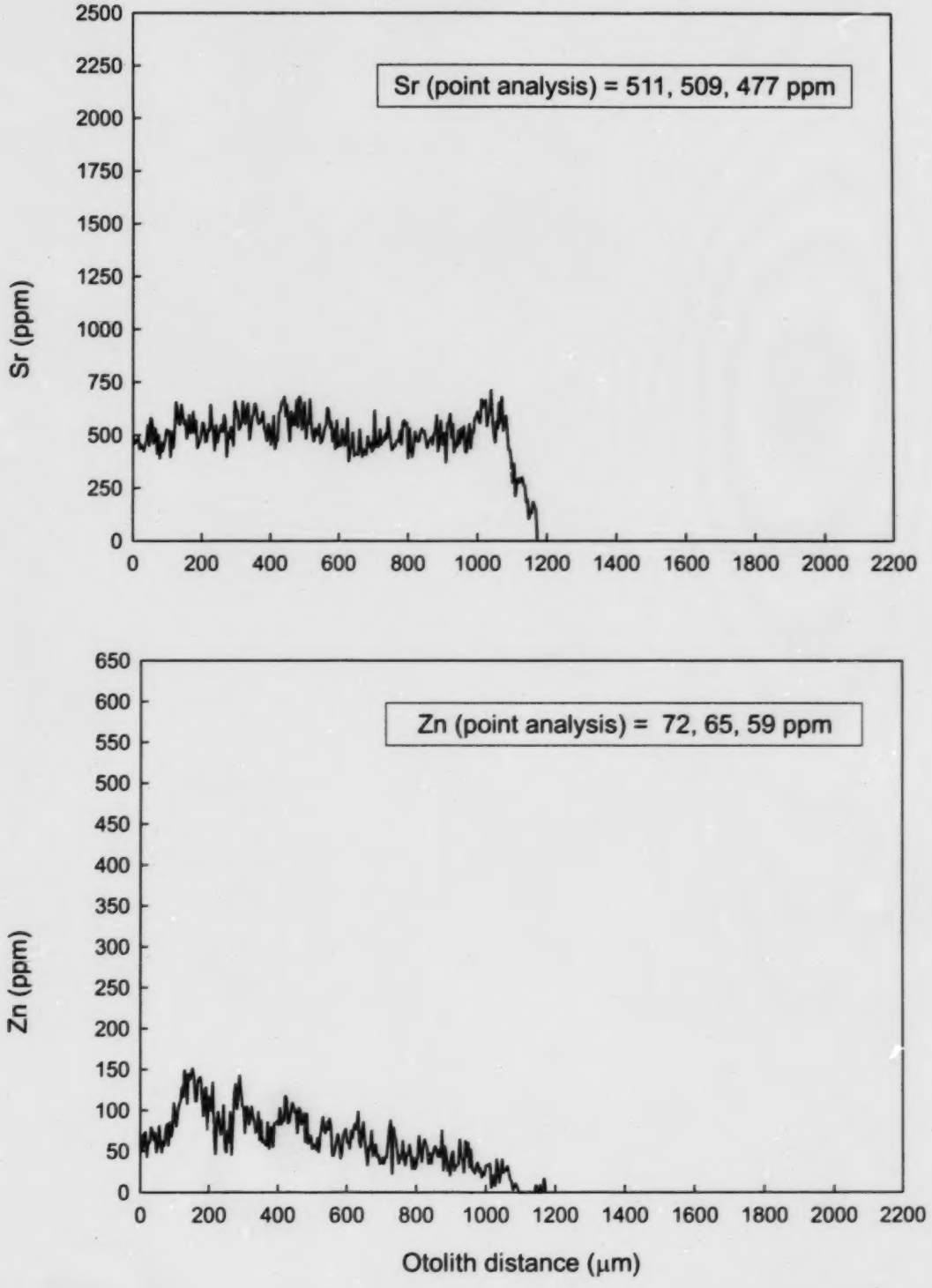

Fig. 32. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (272 mm, 150 g, male, 16 yr) caught in Lake B, May 1996. Point analysis results are also indicated.

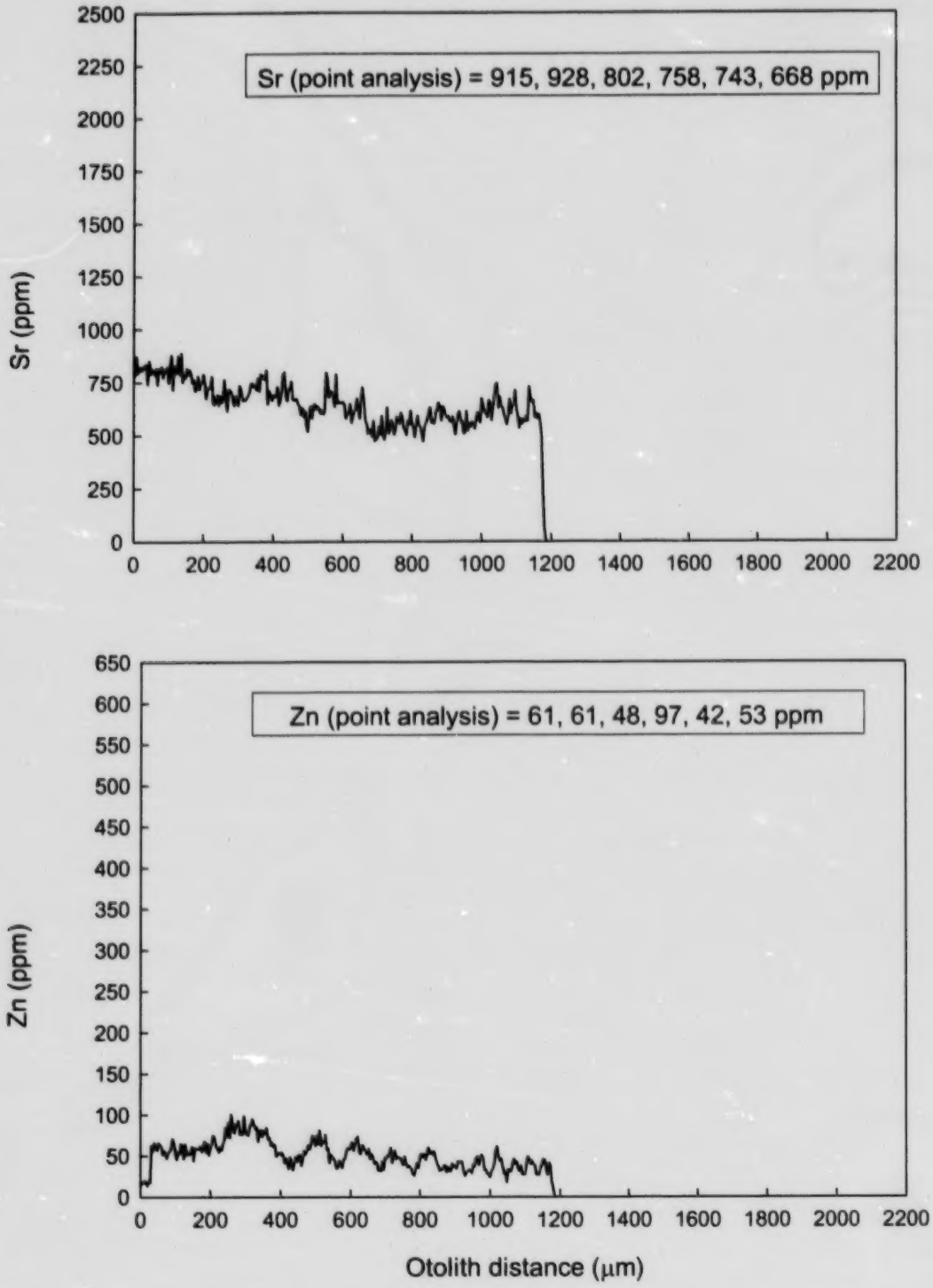

Fig. 33. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (243 mm, 141 g, female, 12 yr) caught in Craig Lake, June 1992. Point analysis results are also indicated.

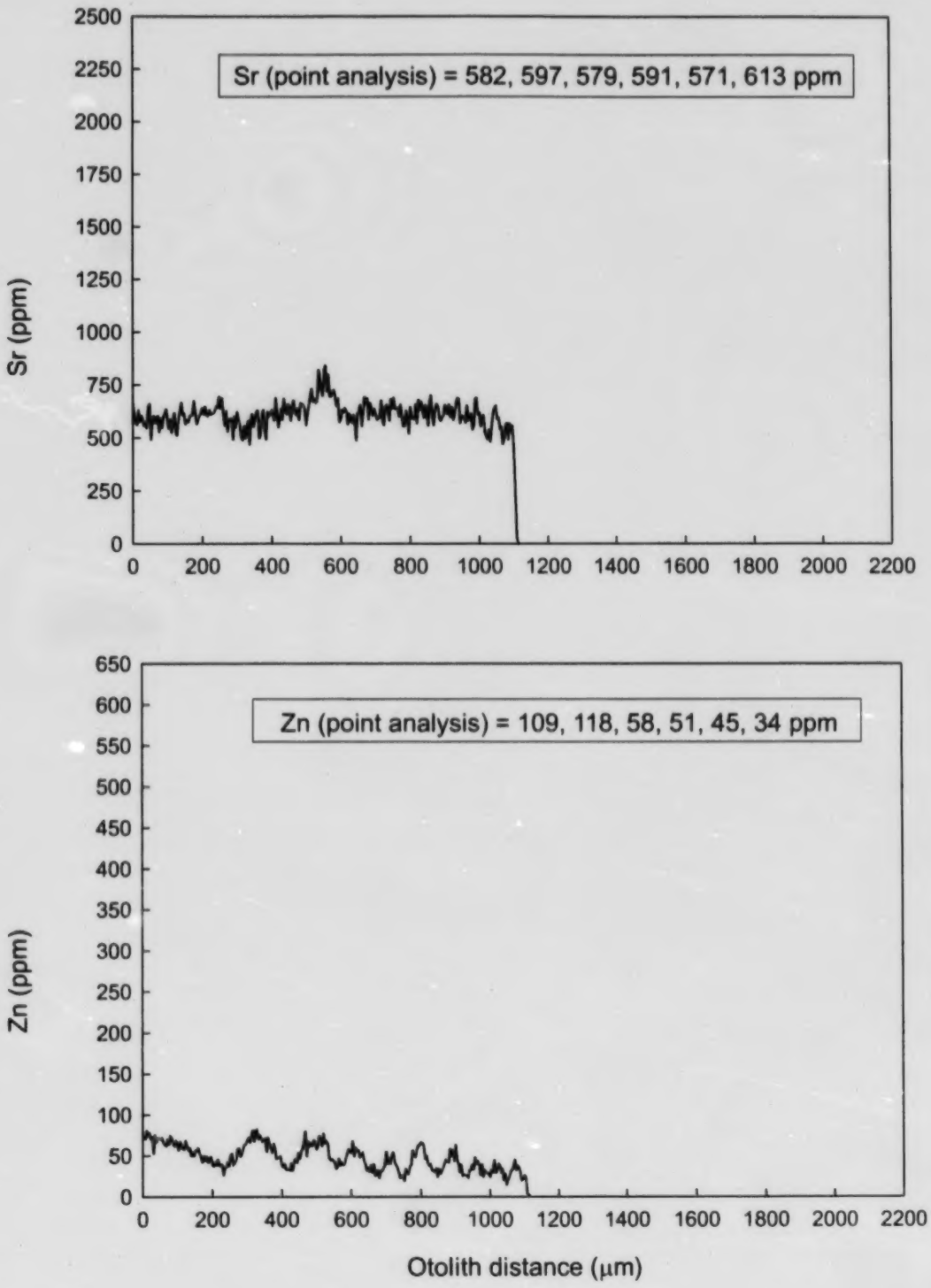

Fig. 34. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (244 mm, 124 g, male, 11 yr) caught in Craig Lake, June 1992. Point analysis results are also indicated.

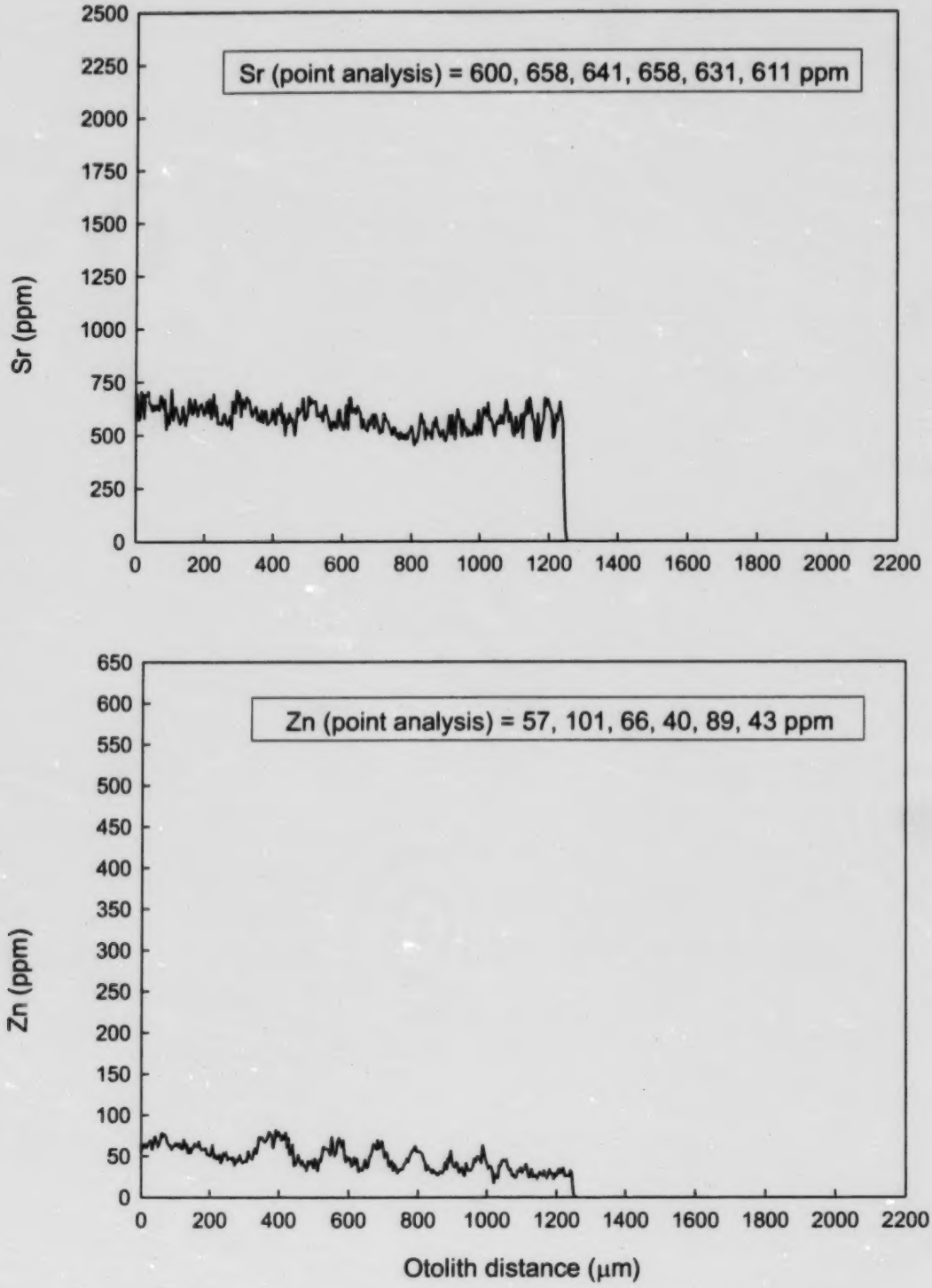

Fig. 35. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (255 mm, 148 g, male, 11 yr) caught in Craig Lake, June 1992. Point analysis results are also indicated.

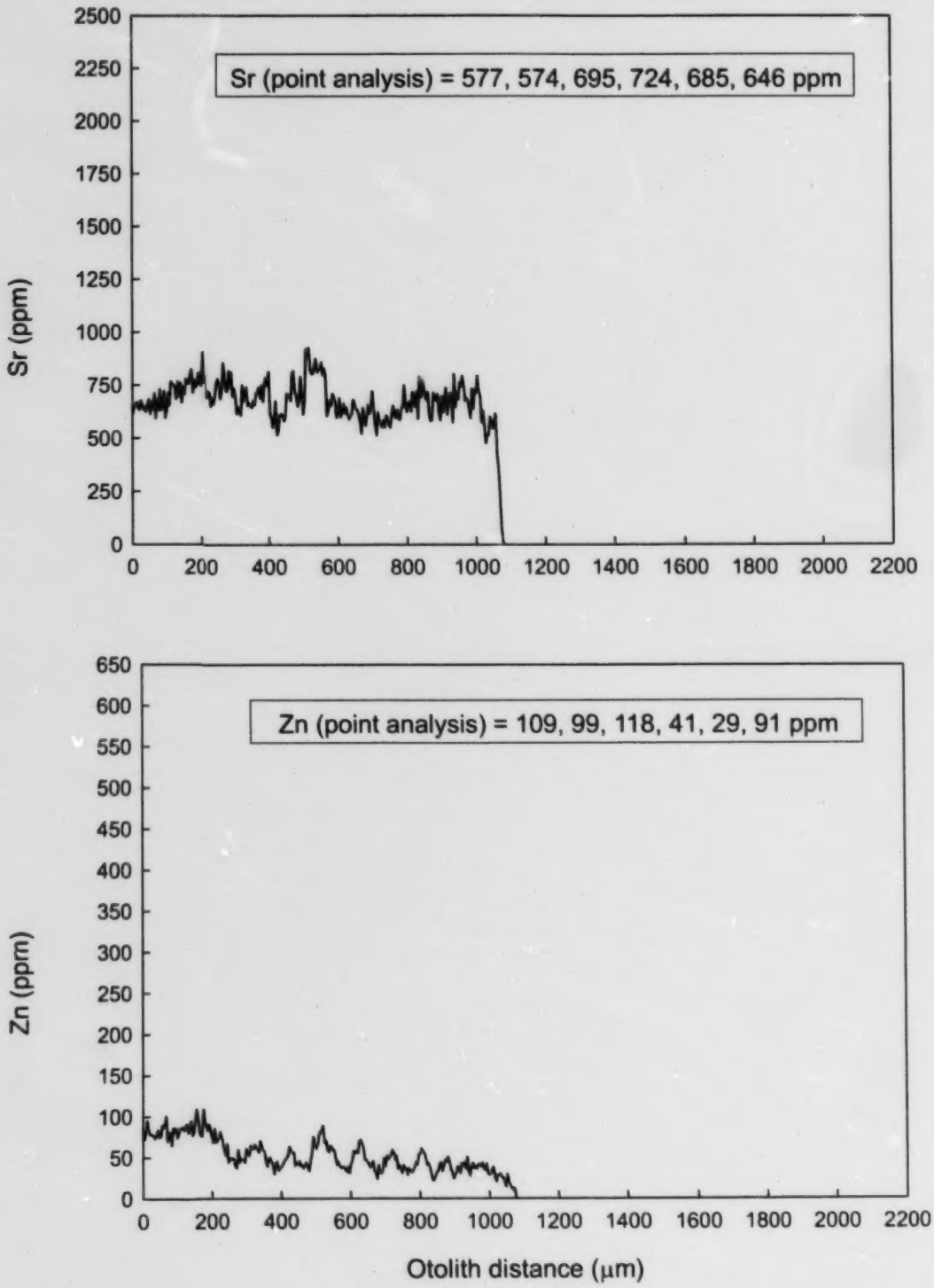

Fig. 36. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (238 mm, 123 g, male, 11 yr) caught in Craig Lake, June 1992. Point analysis results are also indicated.

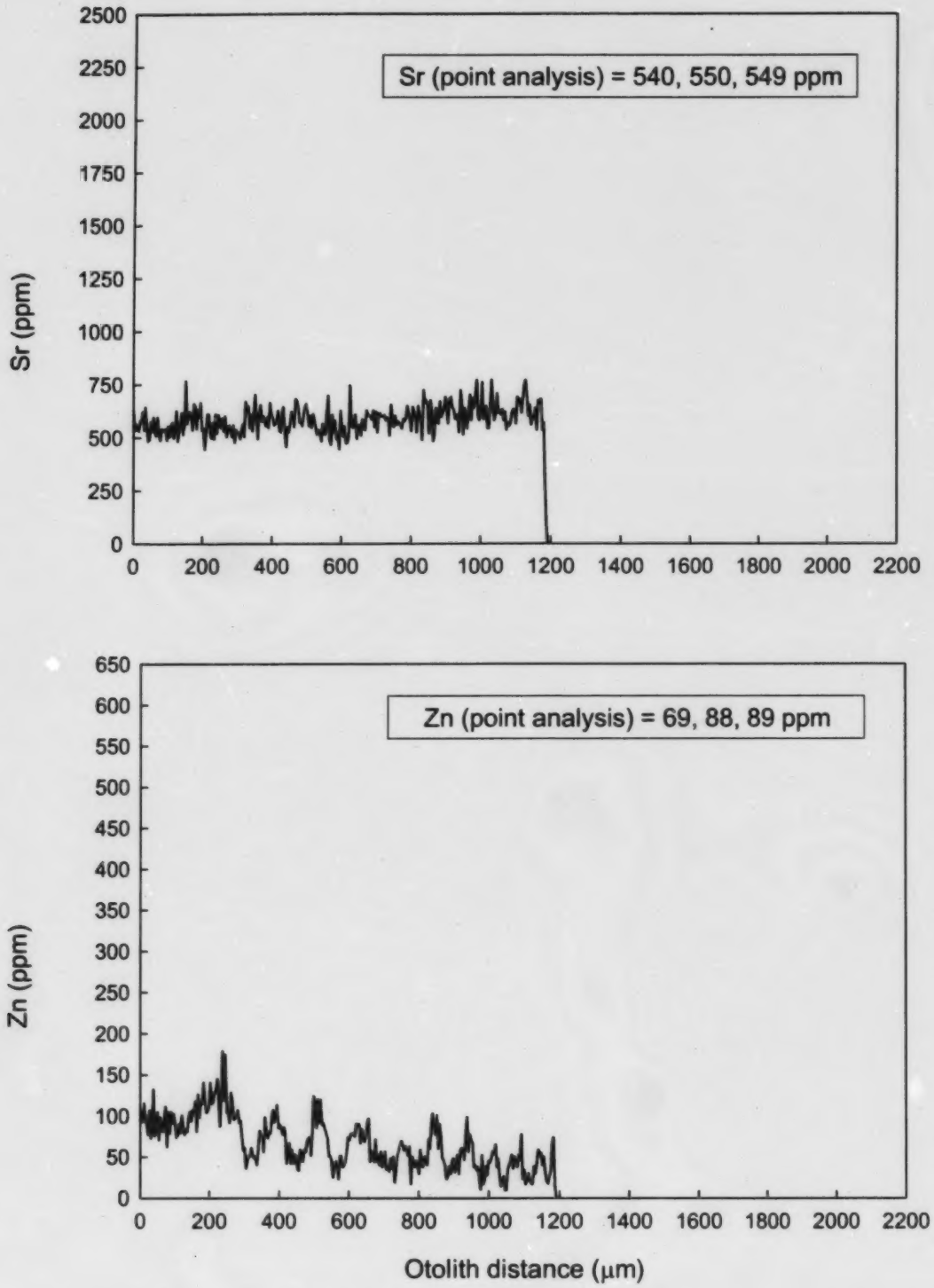

Fig. 37. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (232 mm, 123 g, female, 10 yr) caught in Craig Lake, June 1992. Point analysis results are also indicated.

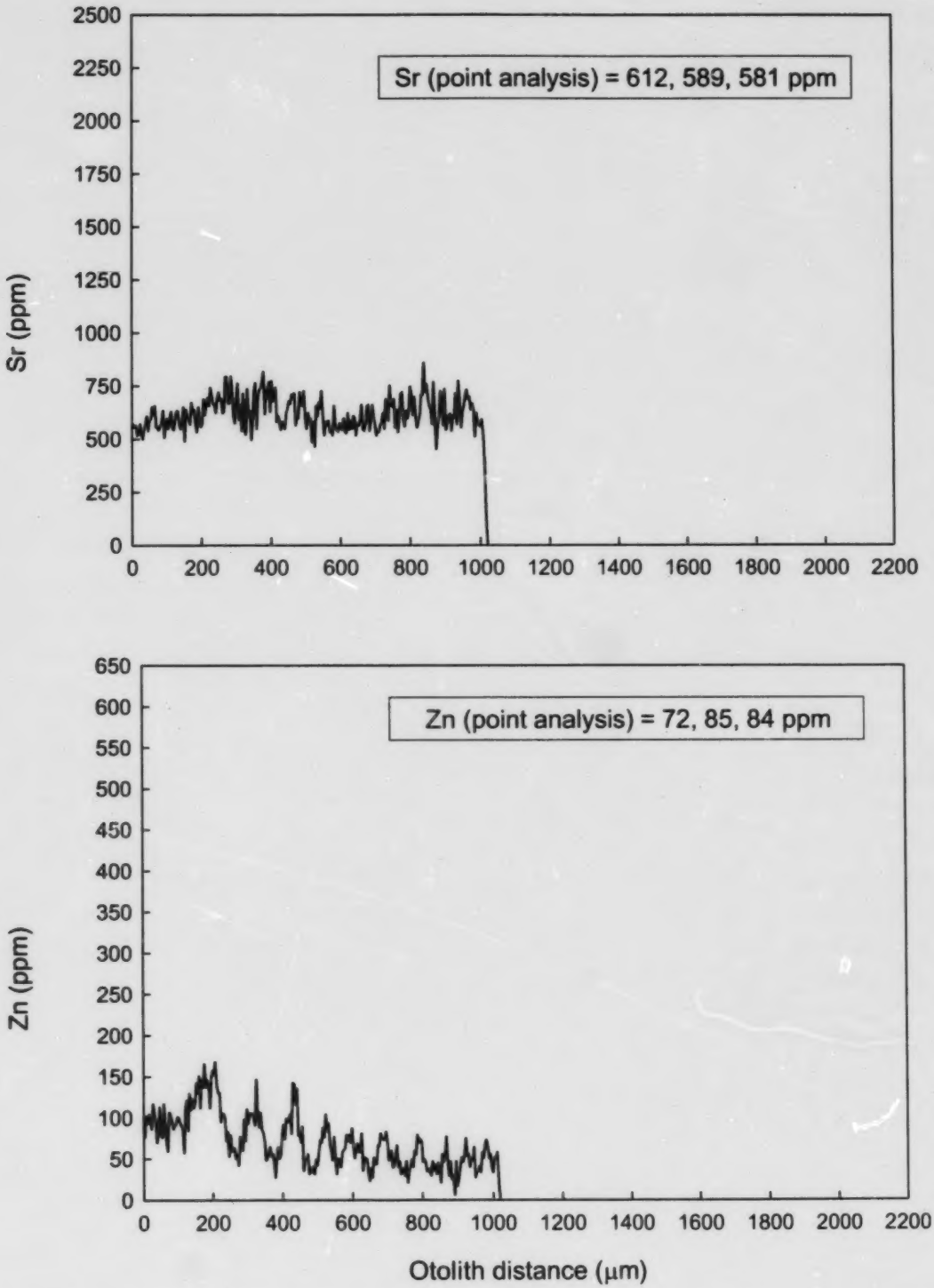

Fig. 38. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (223 mm, 95 g, male, 10 yr) caught in Craig Lake, June 1992. Point analysis results were also indicated.

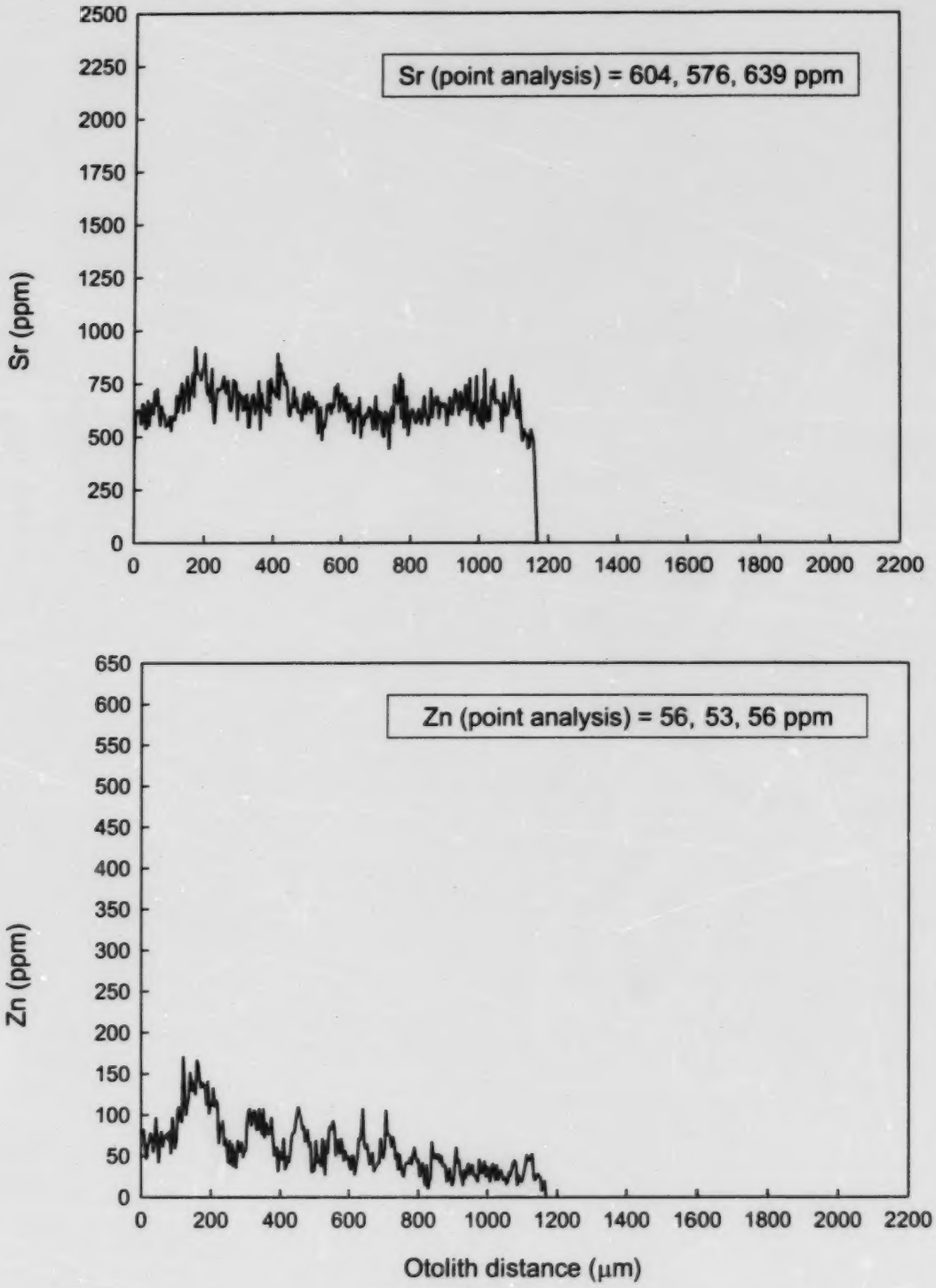

Fig. 39. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (281 mm, 184 g, male, 16 yr) caught in Craig Lake, June 1992. Point analysis results are also indicated.

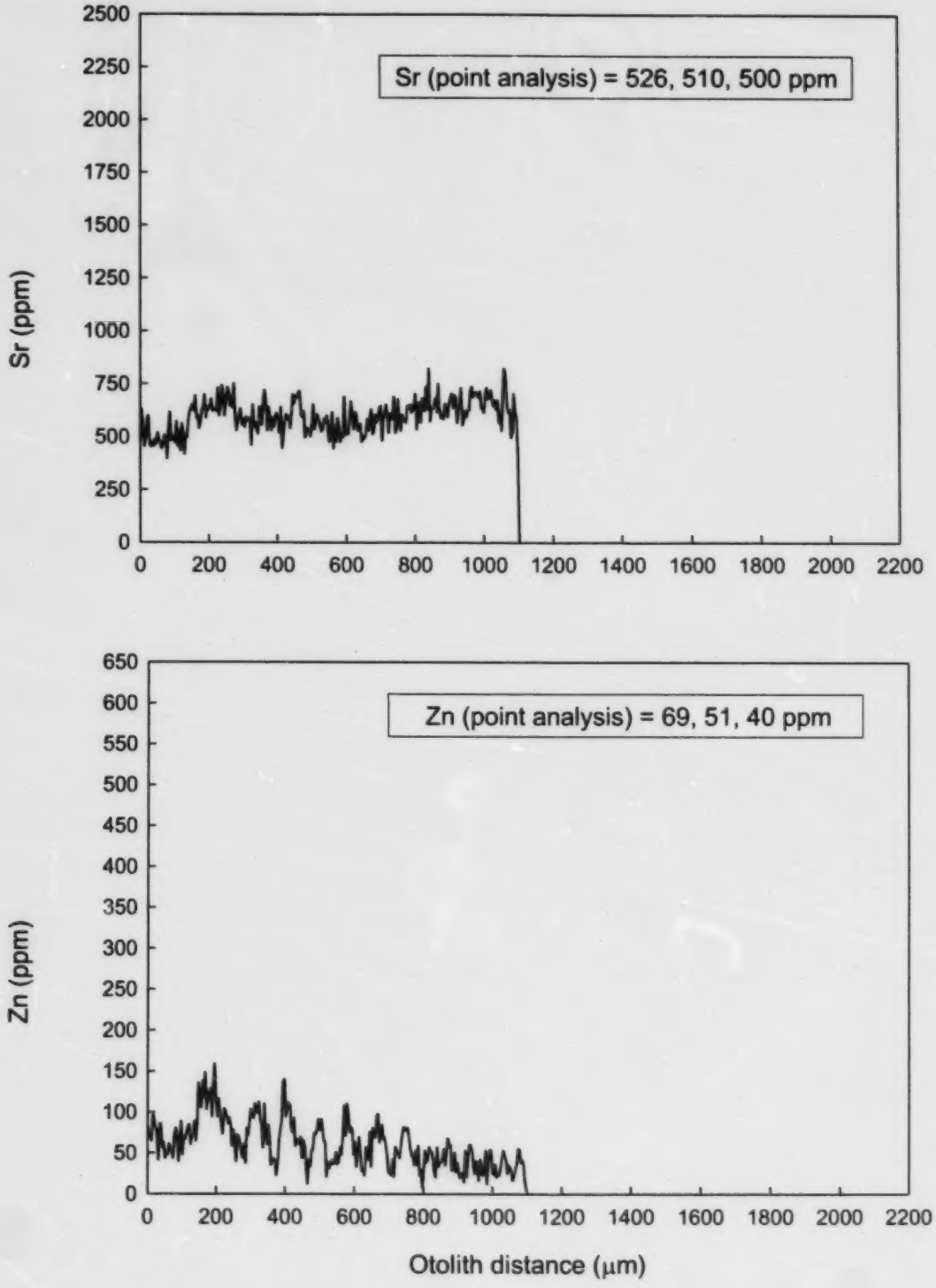

Fig. 40. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (274 mm, 184 g, male, 13 yr) caught in Craig Lake, June 1992. Point analysis results are also indicated.

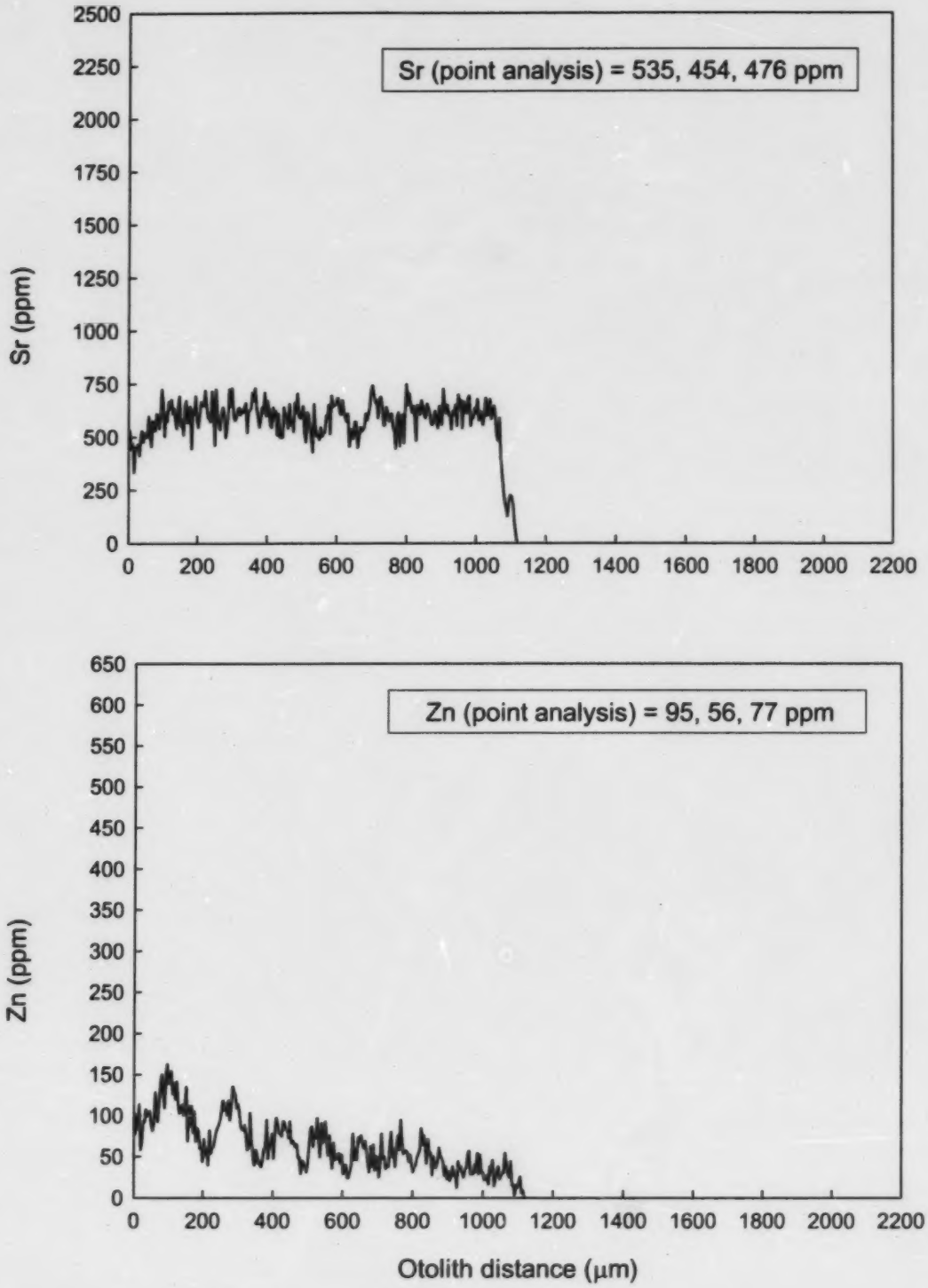

Fig. 41. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (259 mm, 175 g, female, 13 yr) caught in Craig Lake, June 1992. Point analysis results are also indicated.

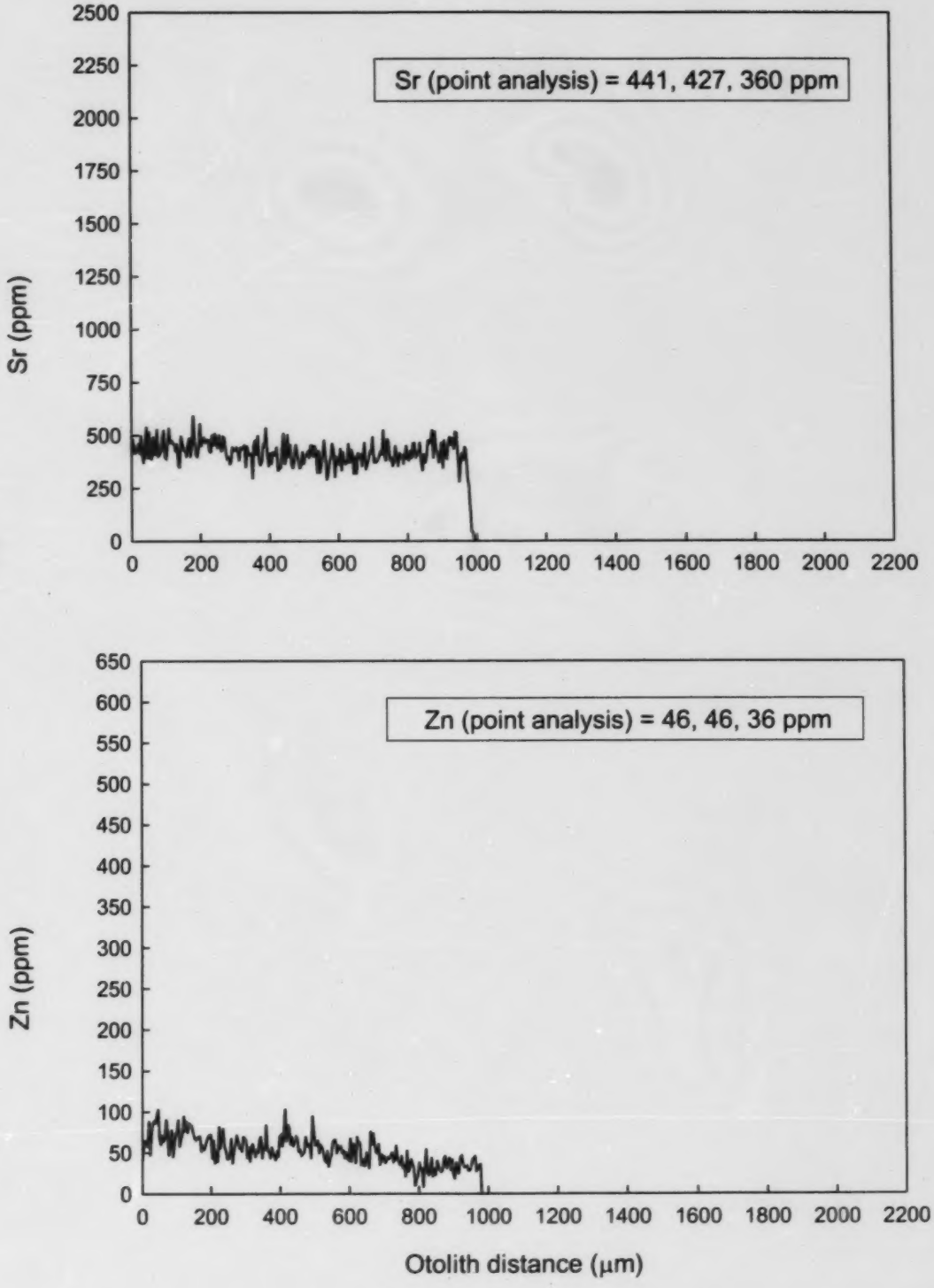

Fig. 42. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (173 mm, 44 g, female, 20 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated.

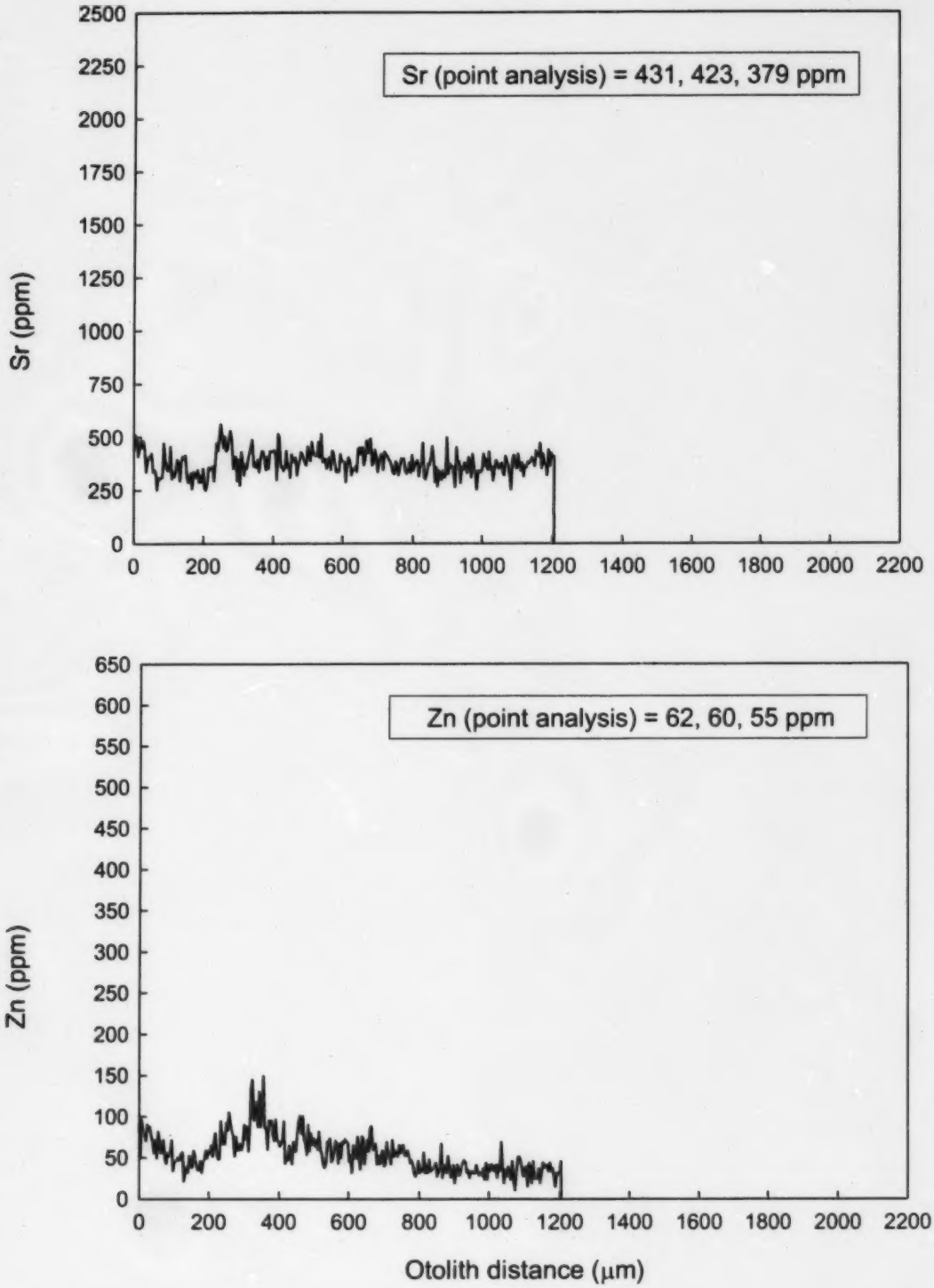

Fig. 43. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (178 mm, 54 g, male, 14 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated.

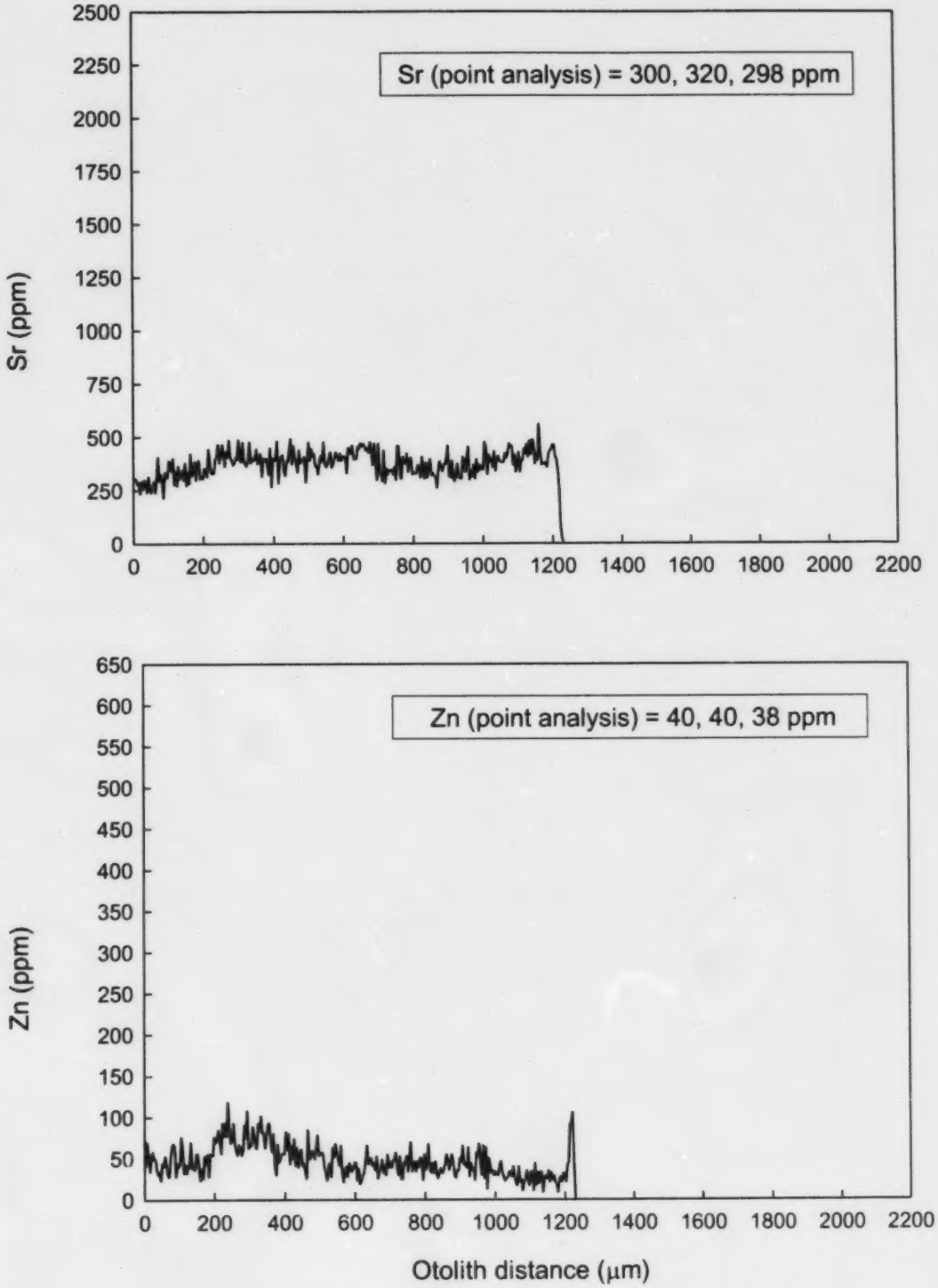

Fig. 44. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (180 mm, 58 g, female, 24 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated.

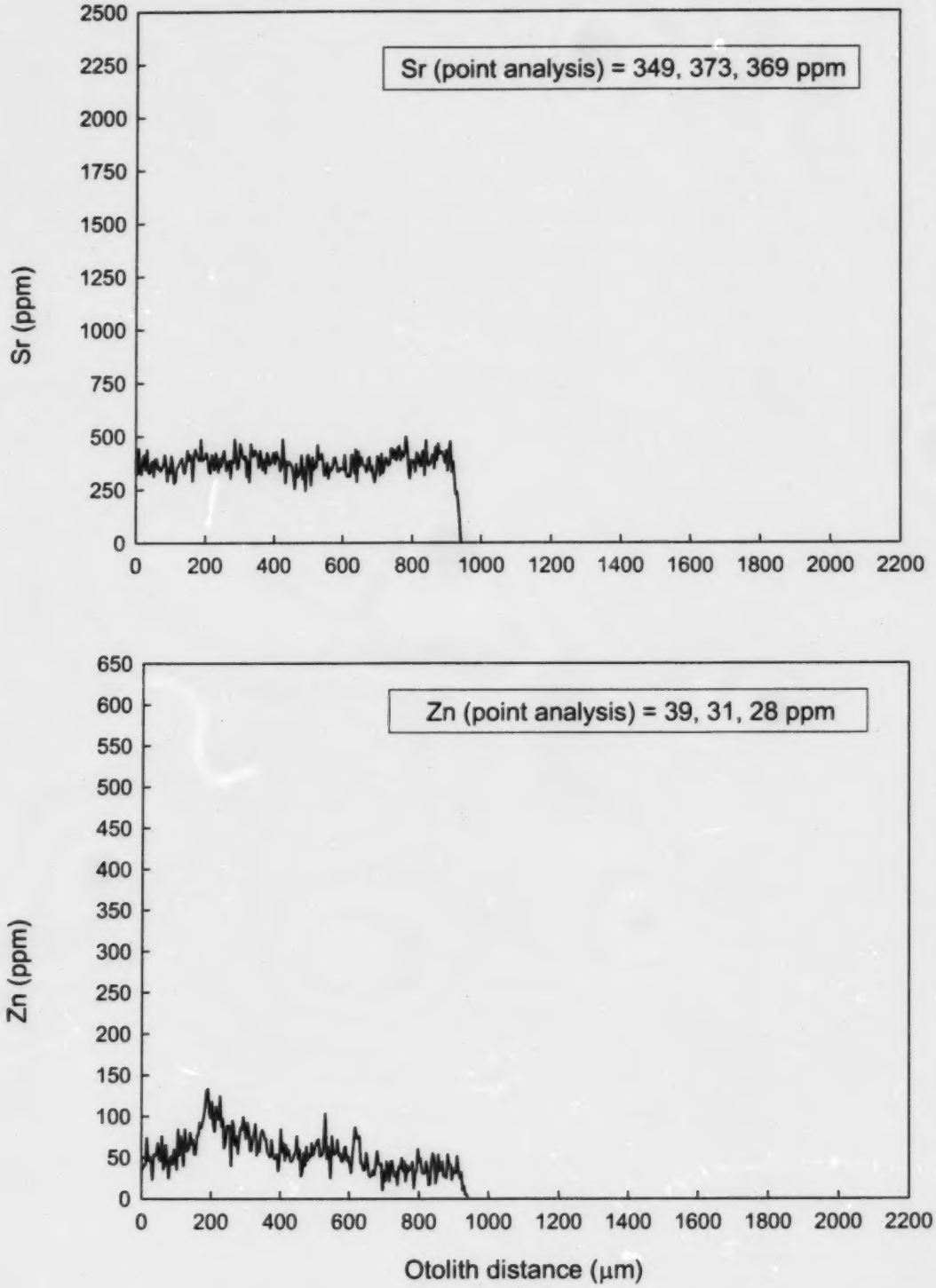

Fig. 45. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (123 mm, 22 g, female, 15 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated.

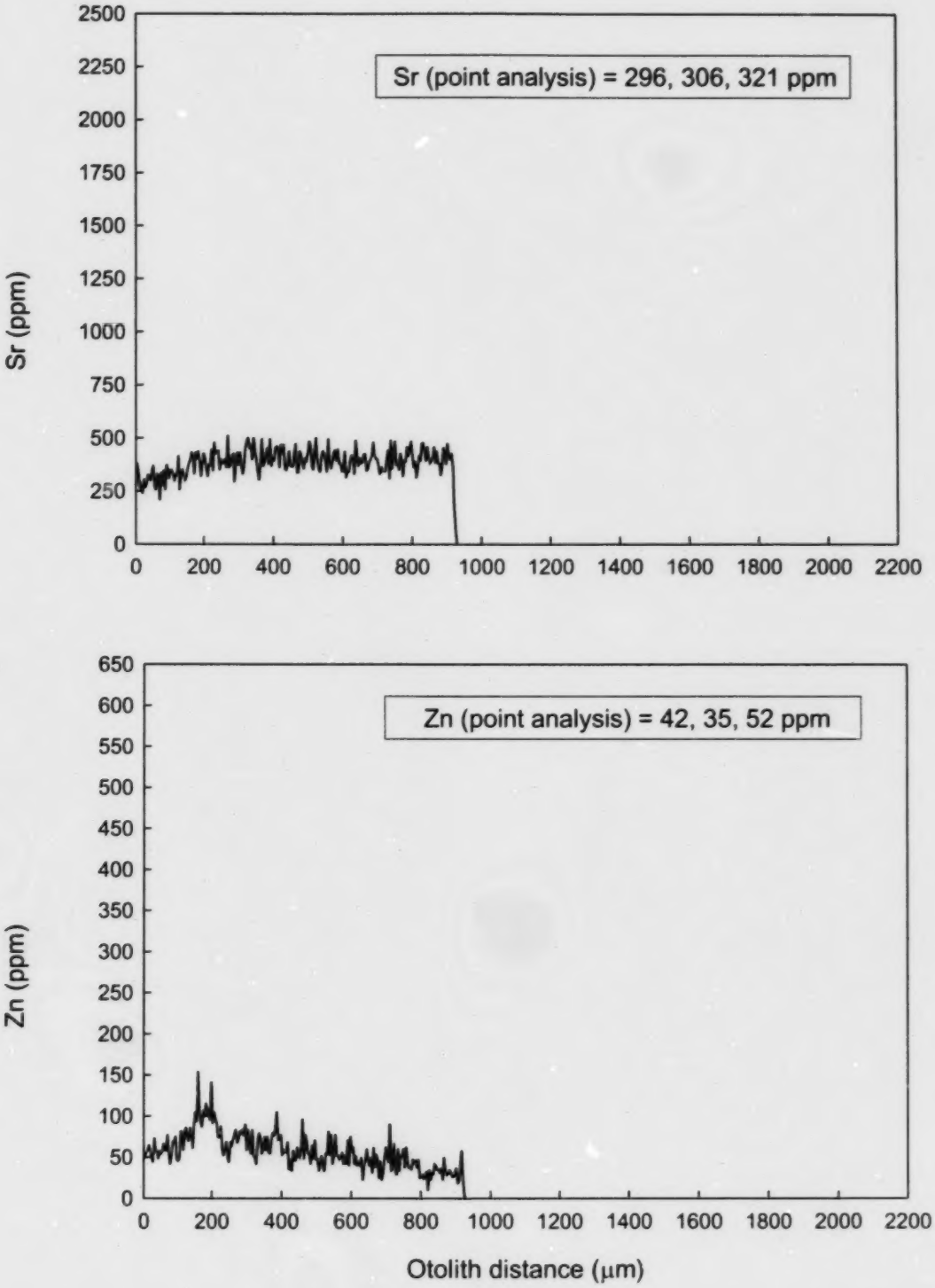

Fig. 46. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (131 mm, 21 g, male, 13 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated.

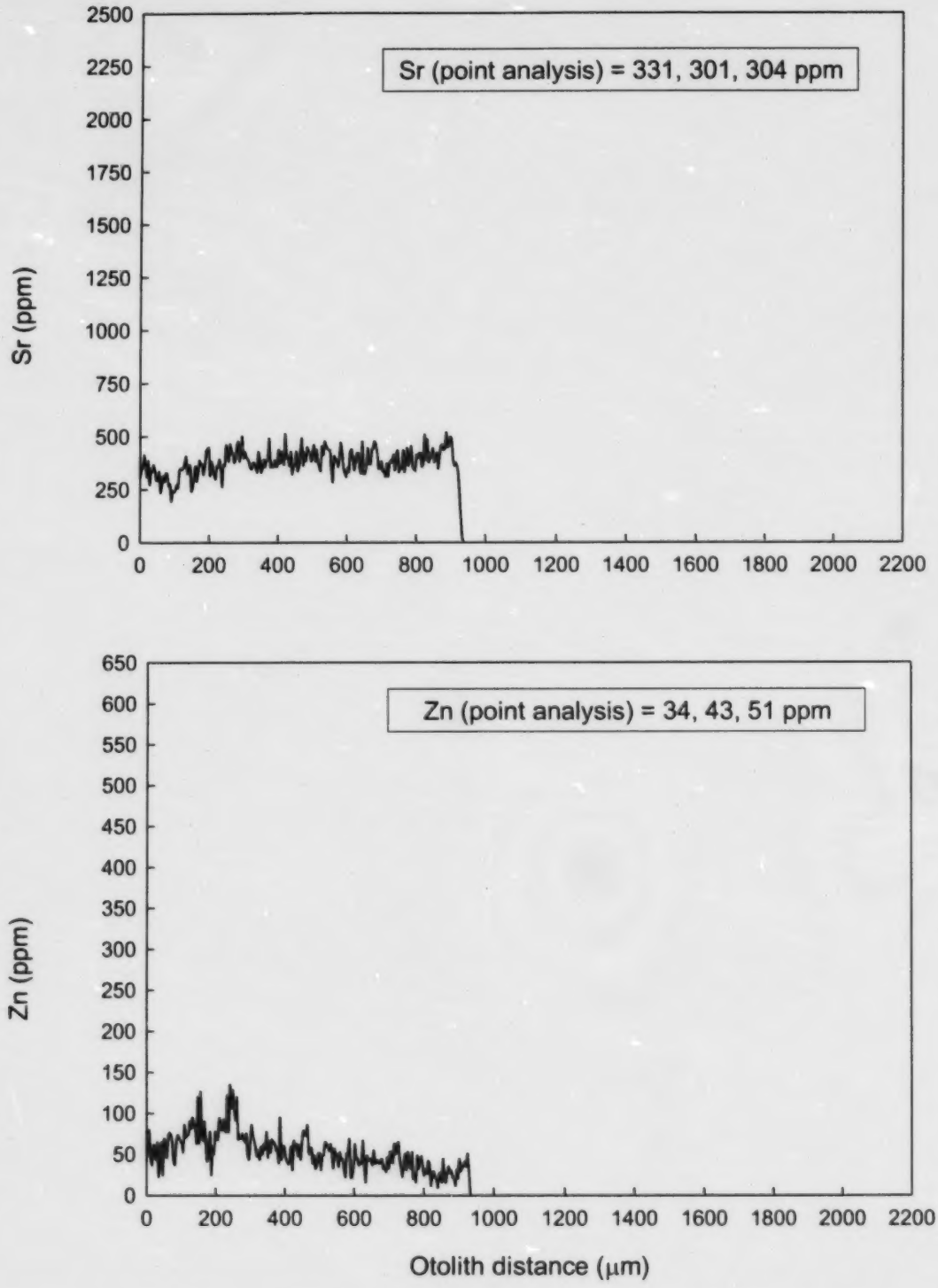

Fig. 47. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (126 mm, 22 g, male, 13 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated.

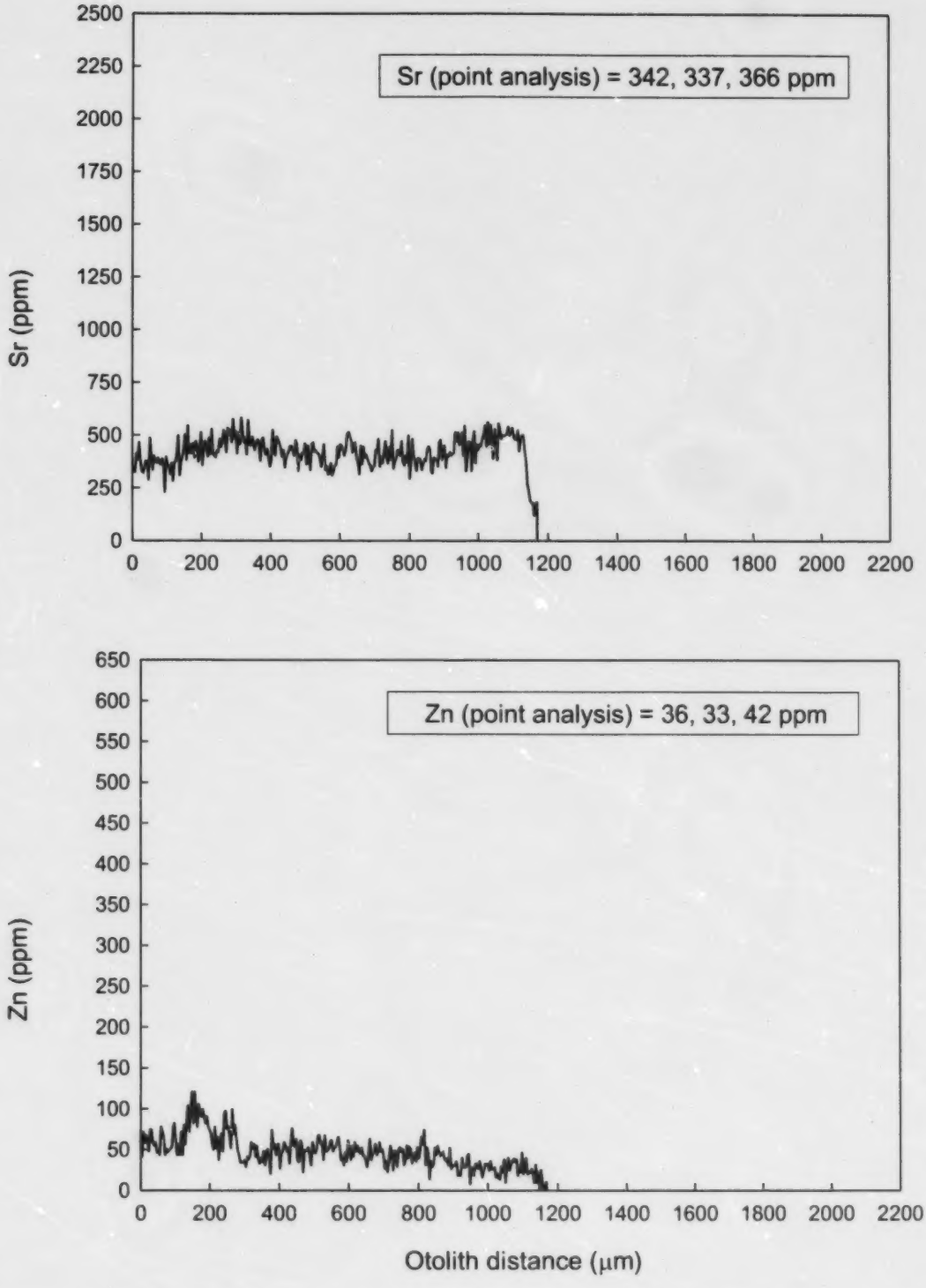

Fig. 48. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (218 mm, 90 g, female, 20 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated,

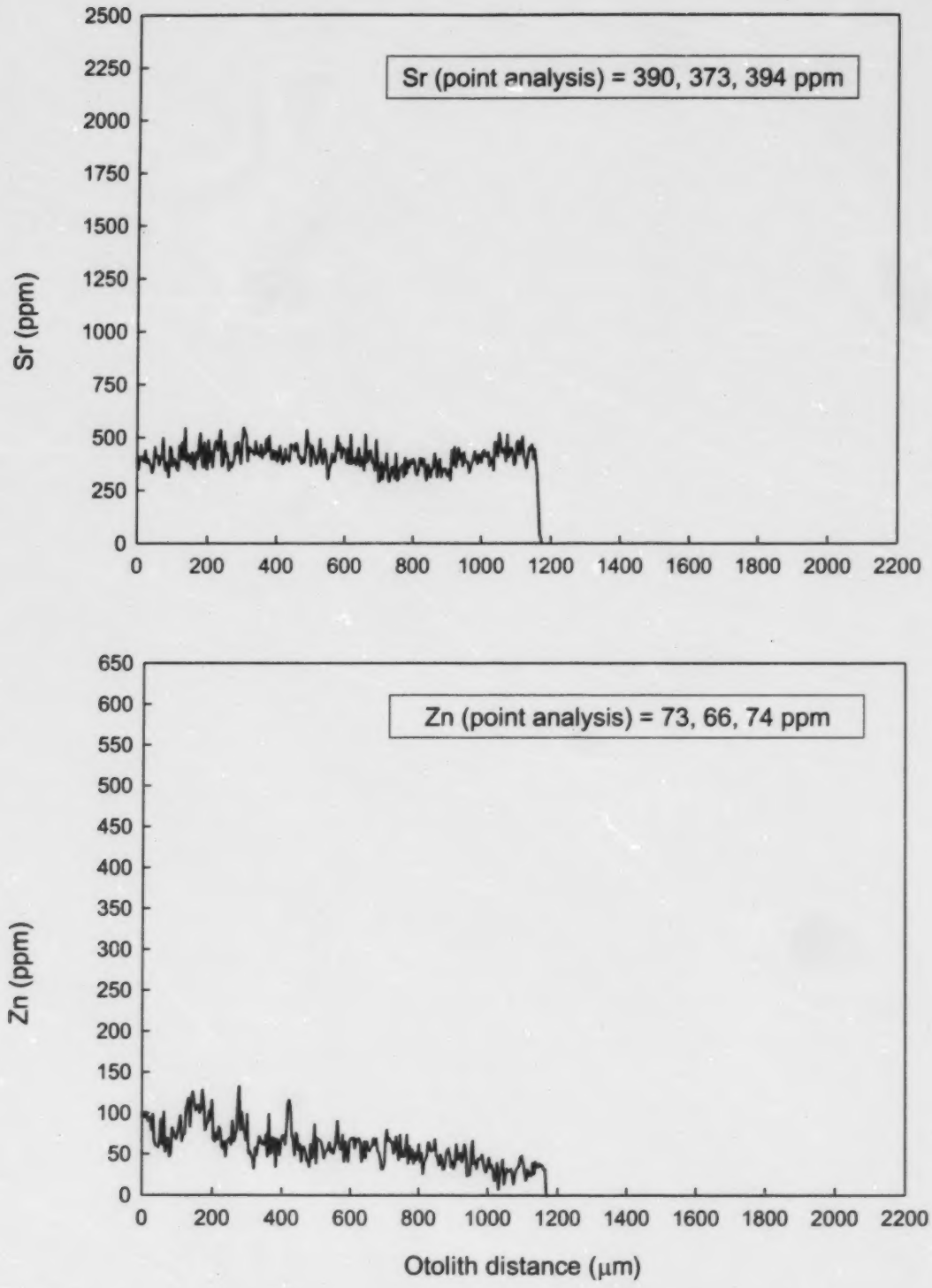

Fig. 49. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (216 mm, 103 g, female, 21 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated.

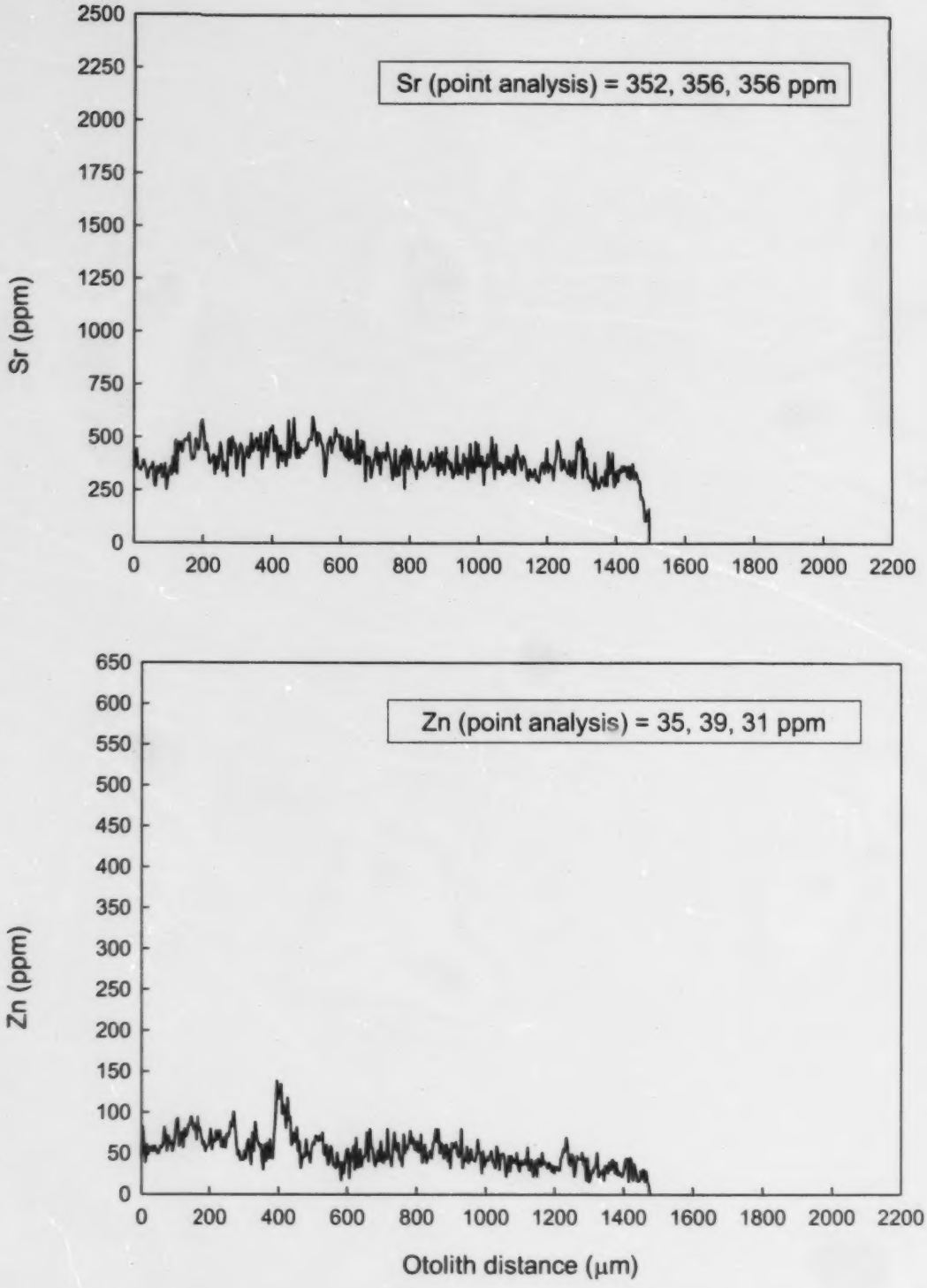

Fig. 50. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (489 mm, 1540 g, male, 20 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated.

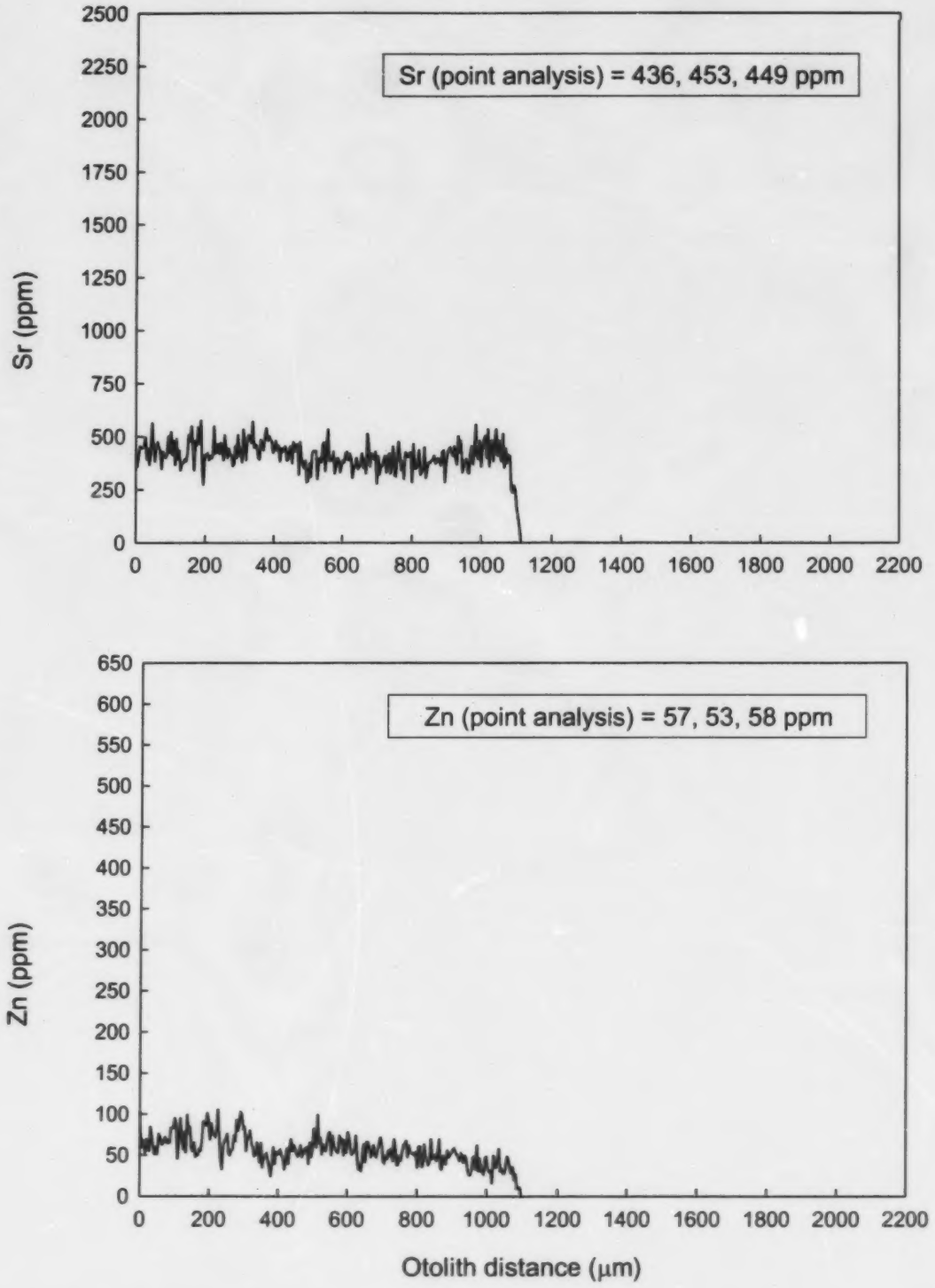

Fig. 51. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (170 mm, 46 g, female, 21 yr) caught in Ekblaw Lake, July 1998. Point analysis results are also indicated.

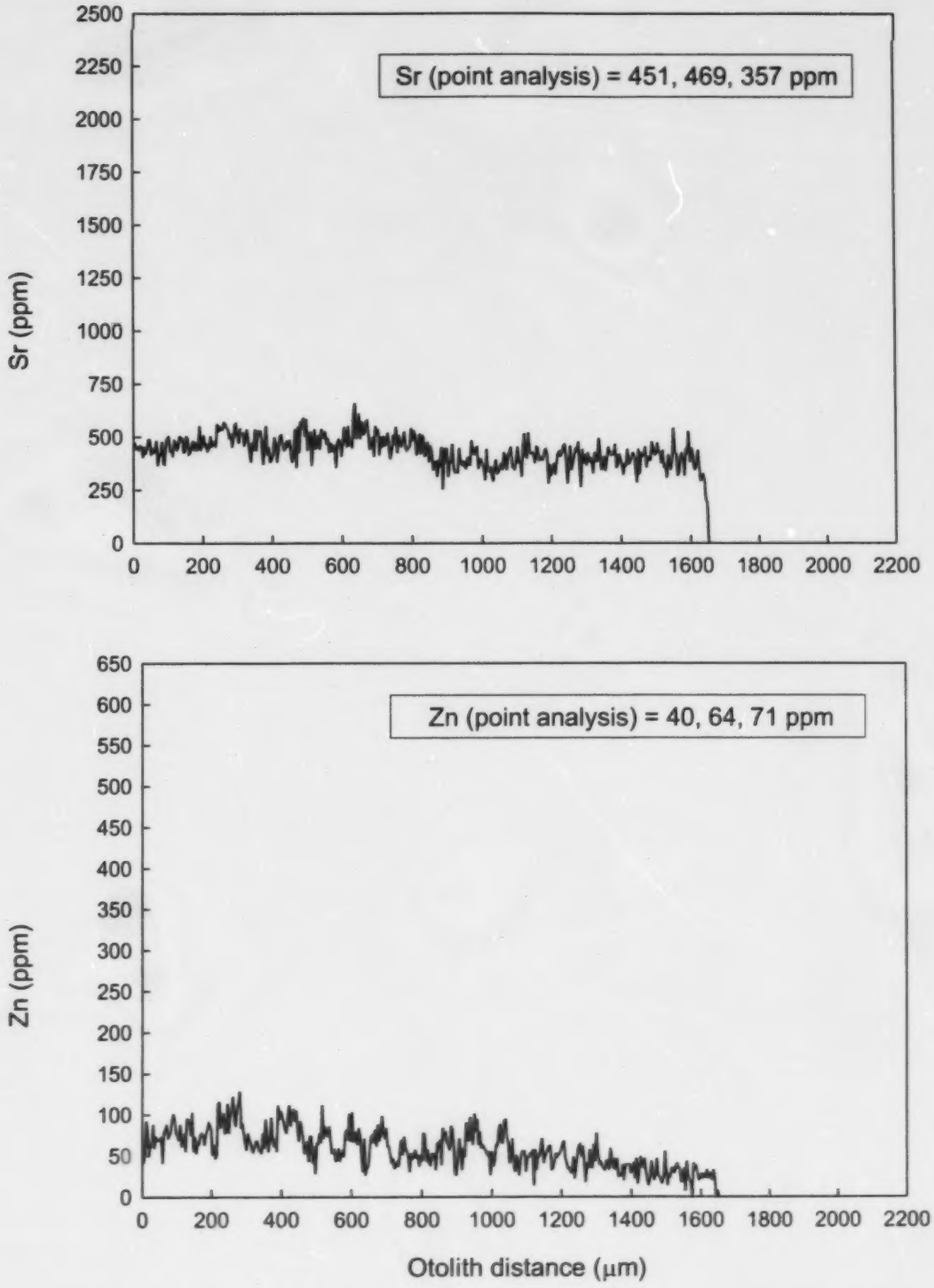

Fig. 52. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (633 mm, 2450 g, male, 20 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

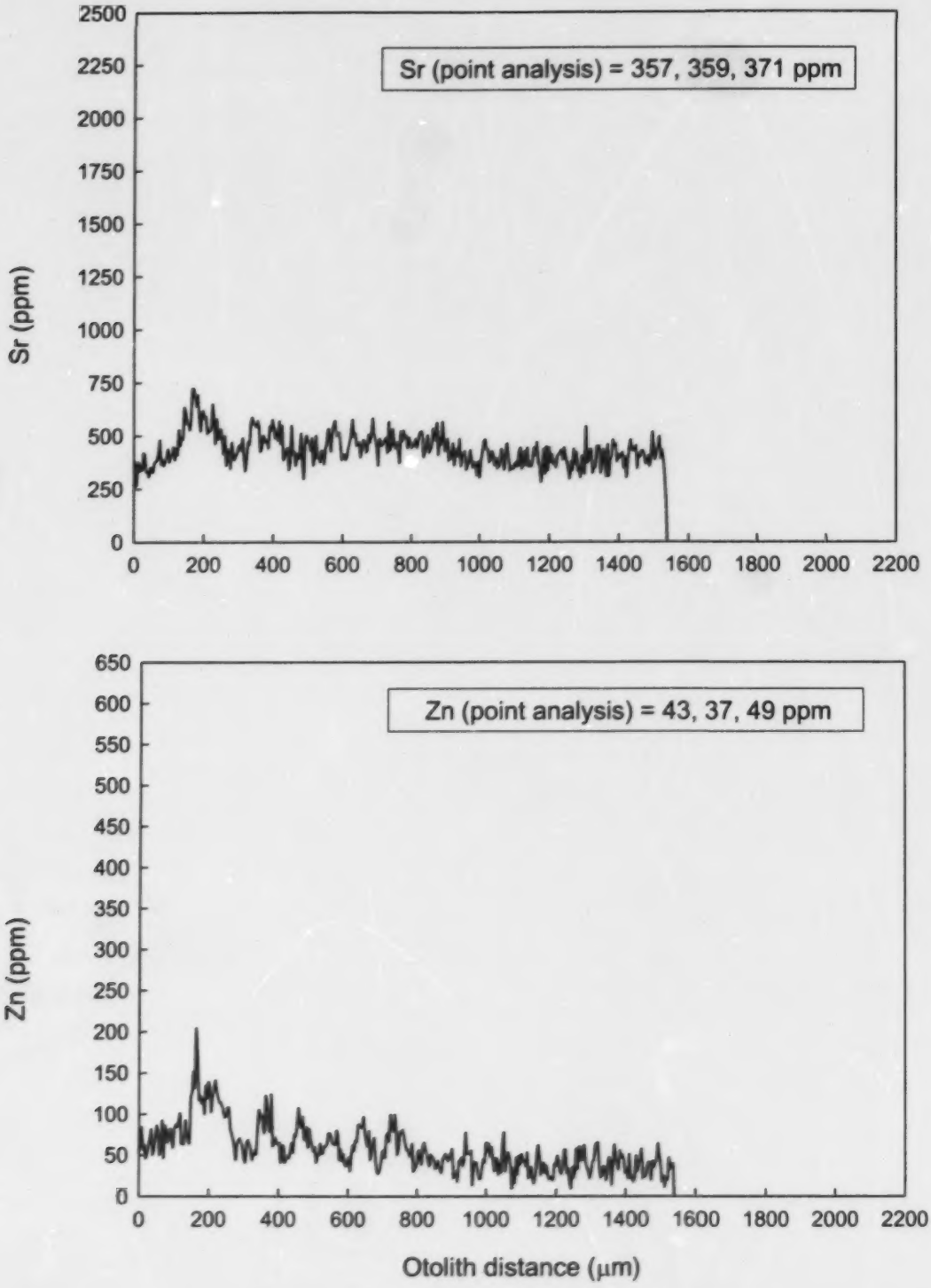

Fig. 53. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (347 mm, 450 g, male, not aged) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

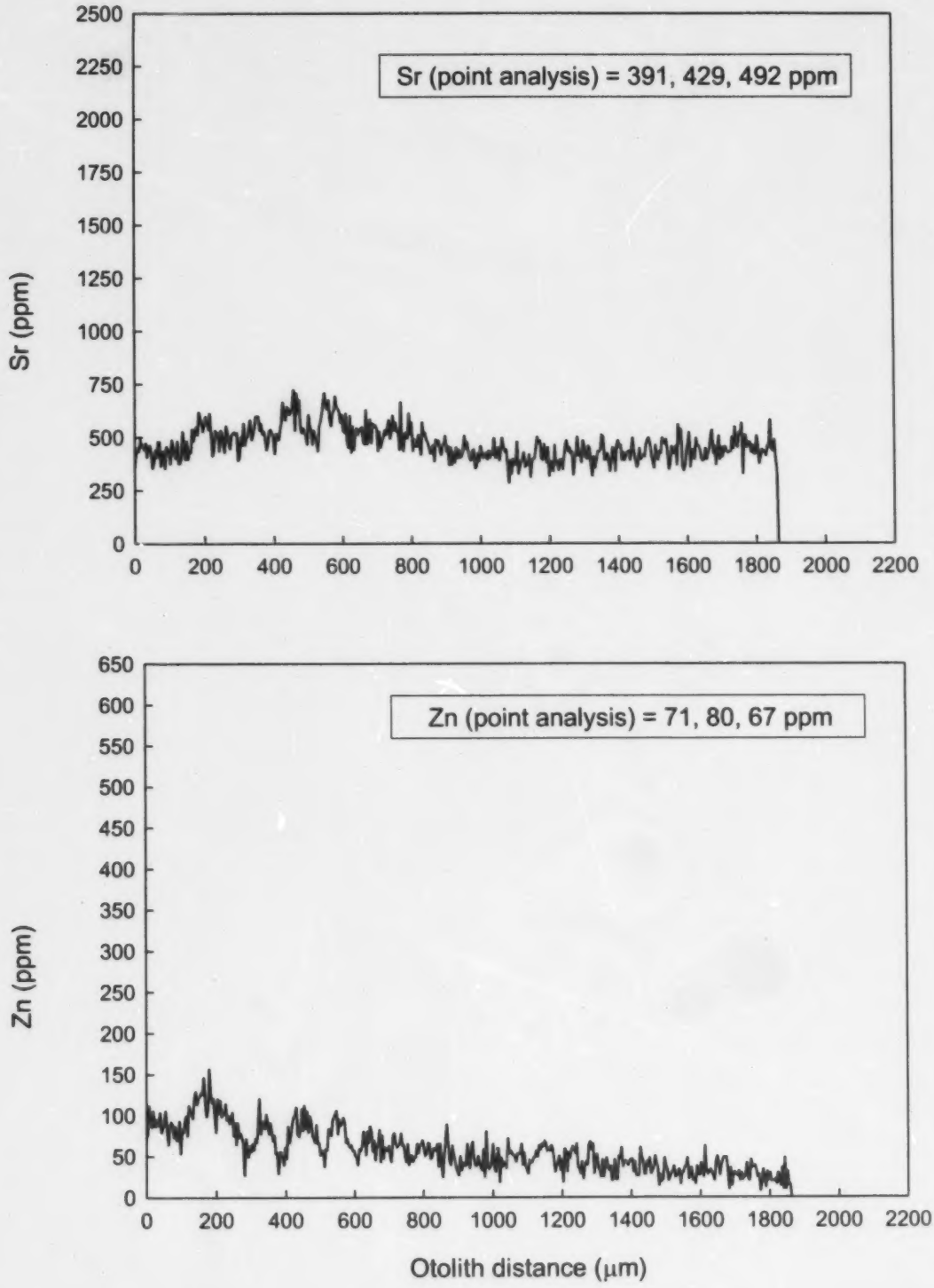

Fig. 54. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (574 mm, 1475 g, male, 25 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

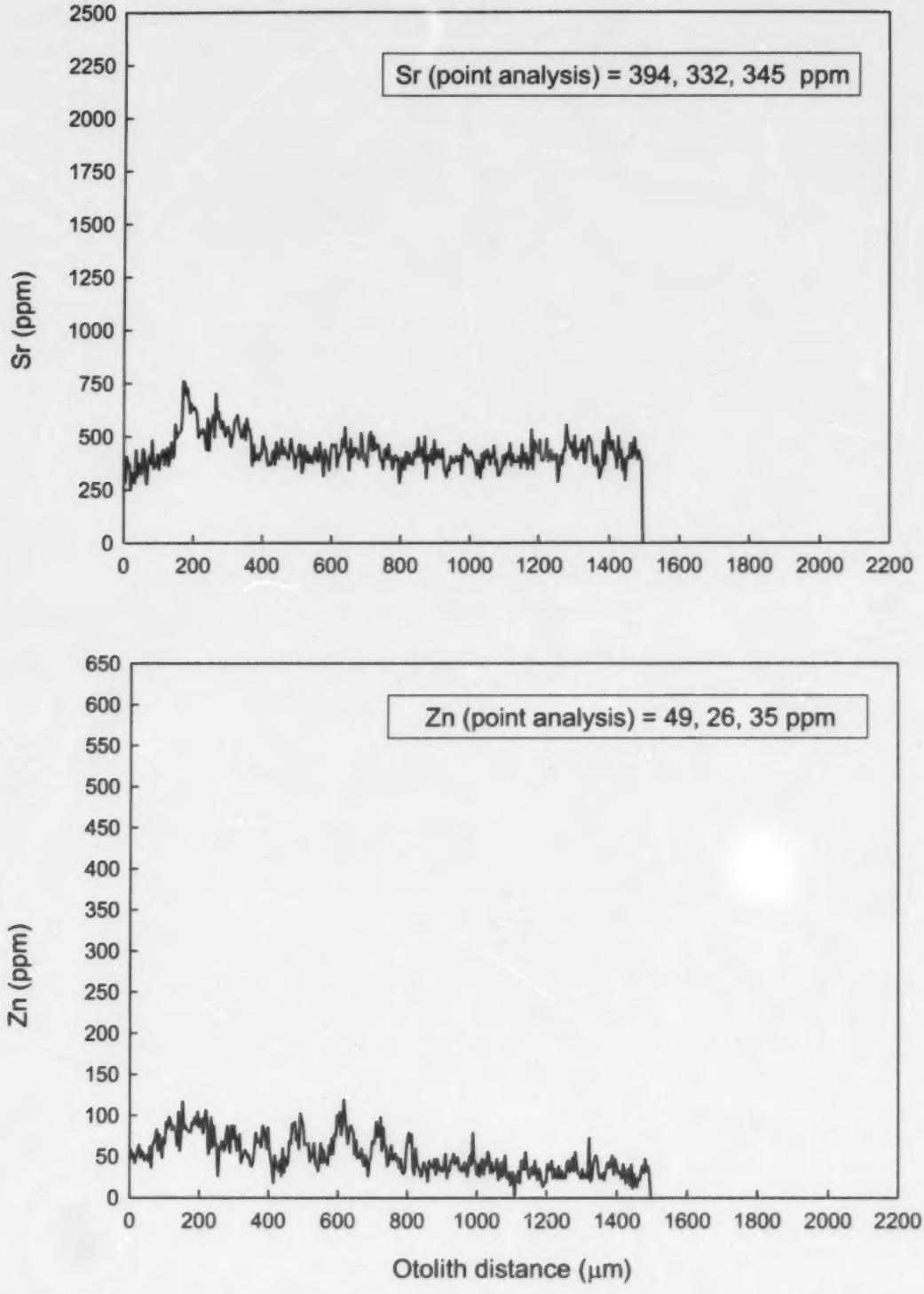

Fig. 55. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (420 mm, 625 g, male,18 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

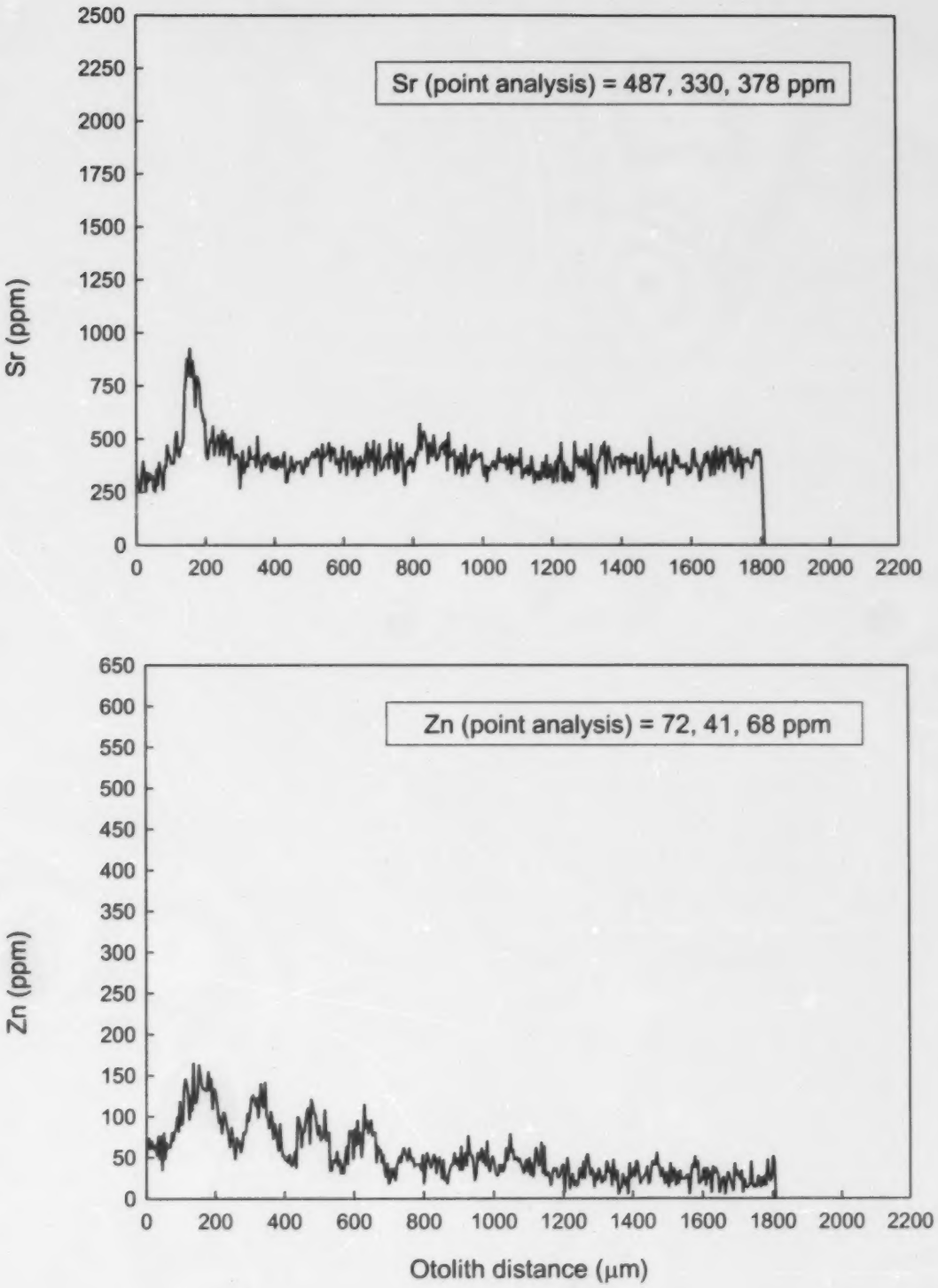

Fig. 56. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (717 mm, 4800 g, male, 22 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

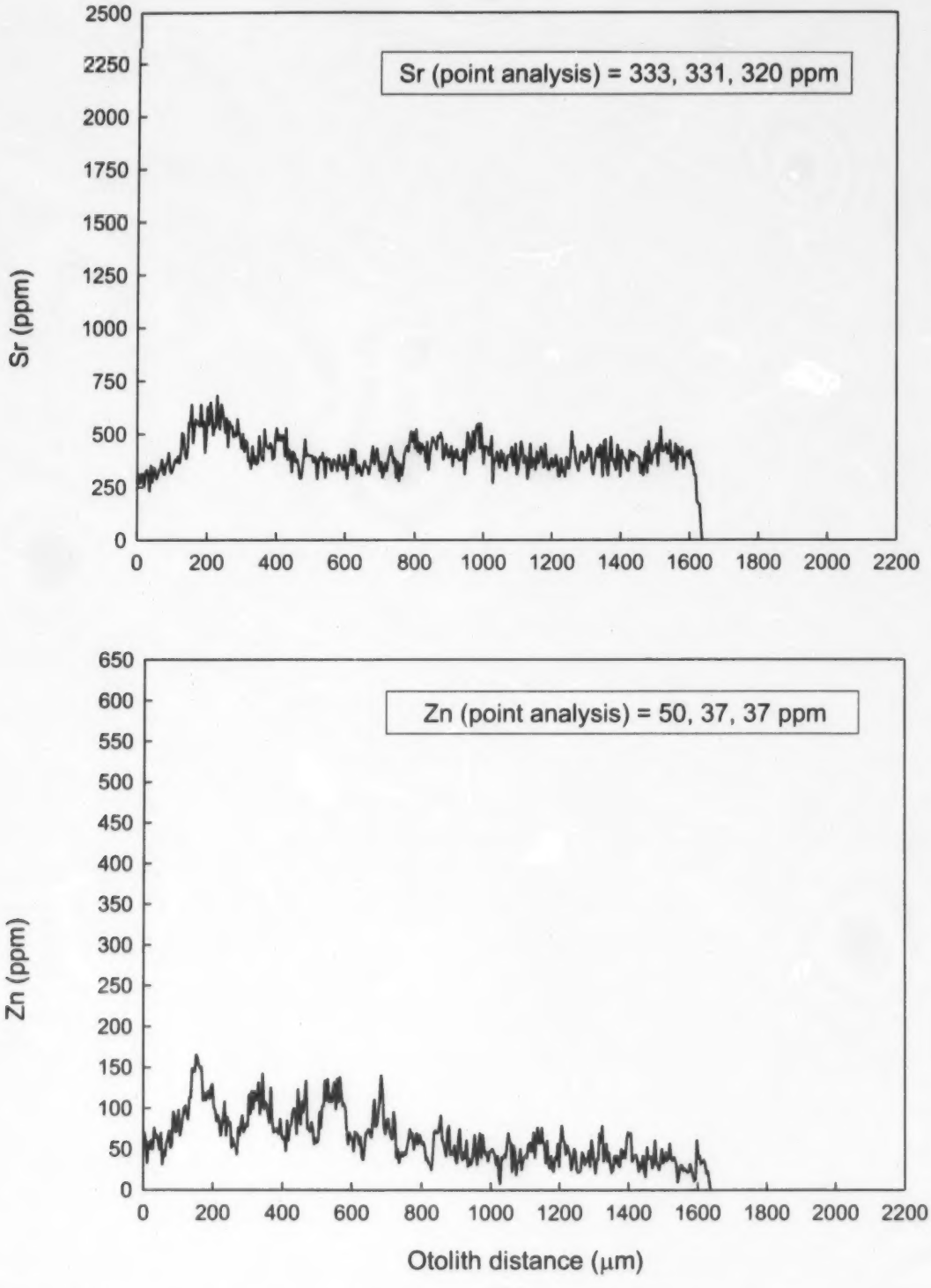

Fig. 57. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (610 mm, 2250 g, male, 19 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

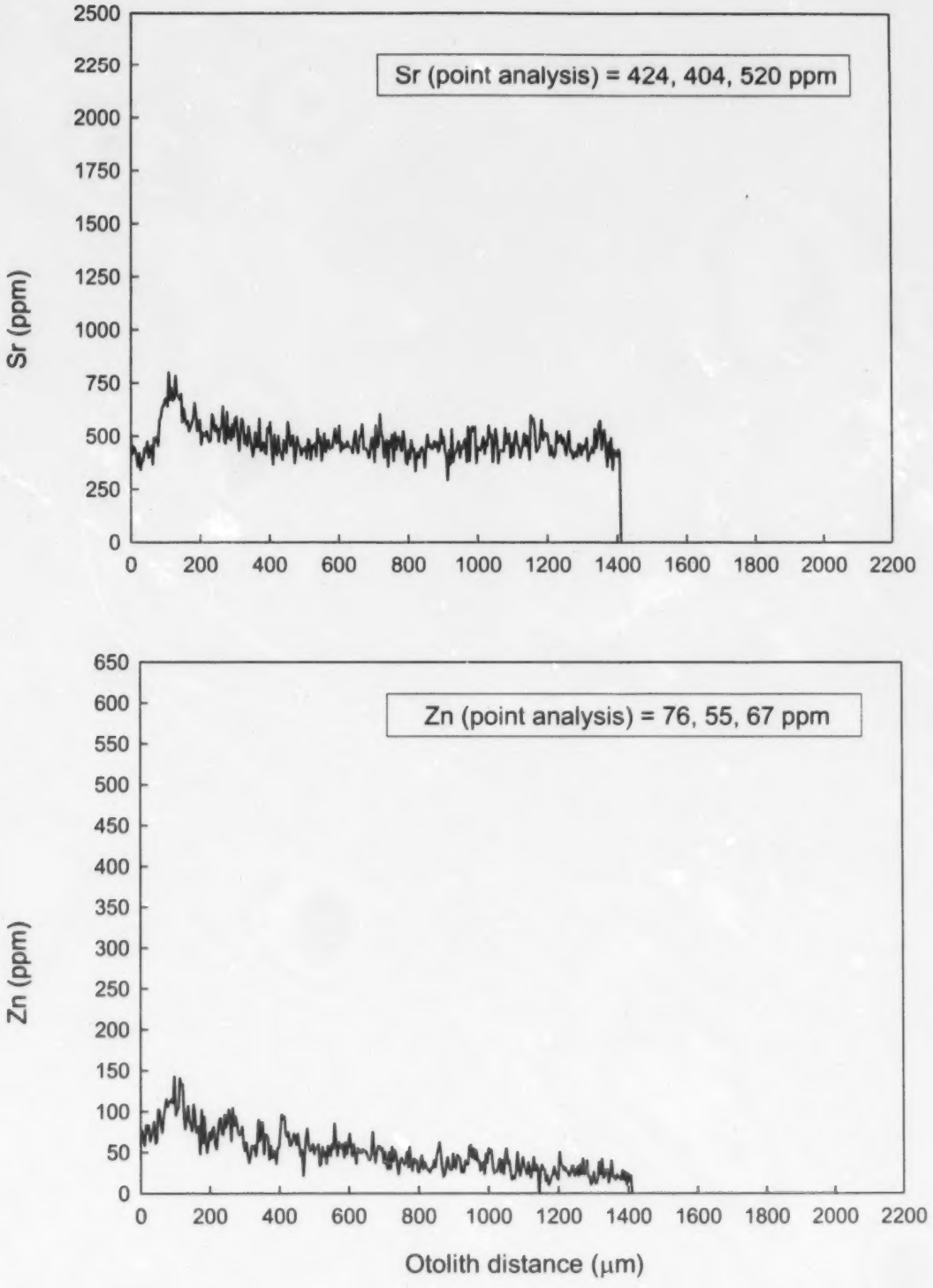

Fig. 58. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (390 mm, 600 g, female, 23 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

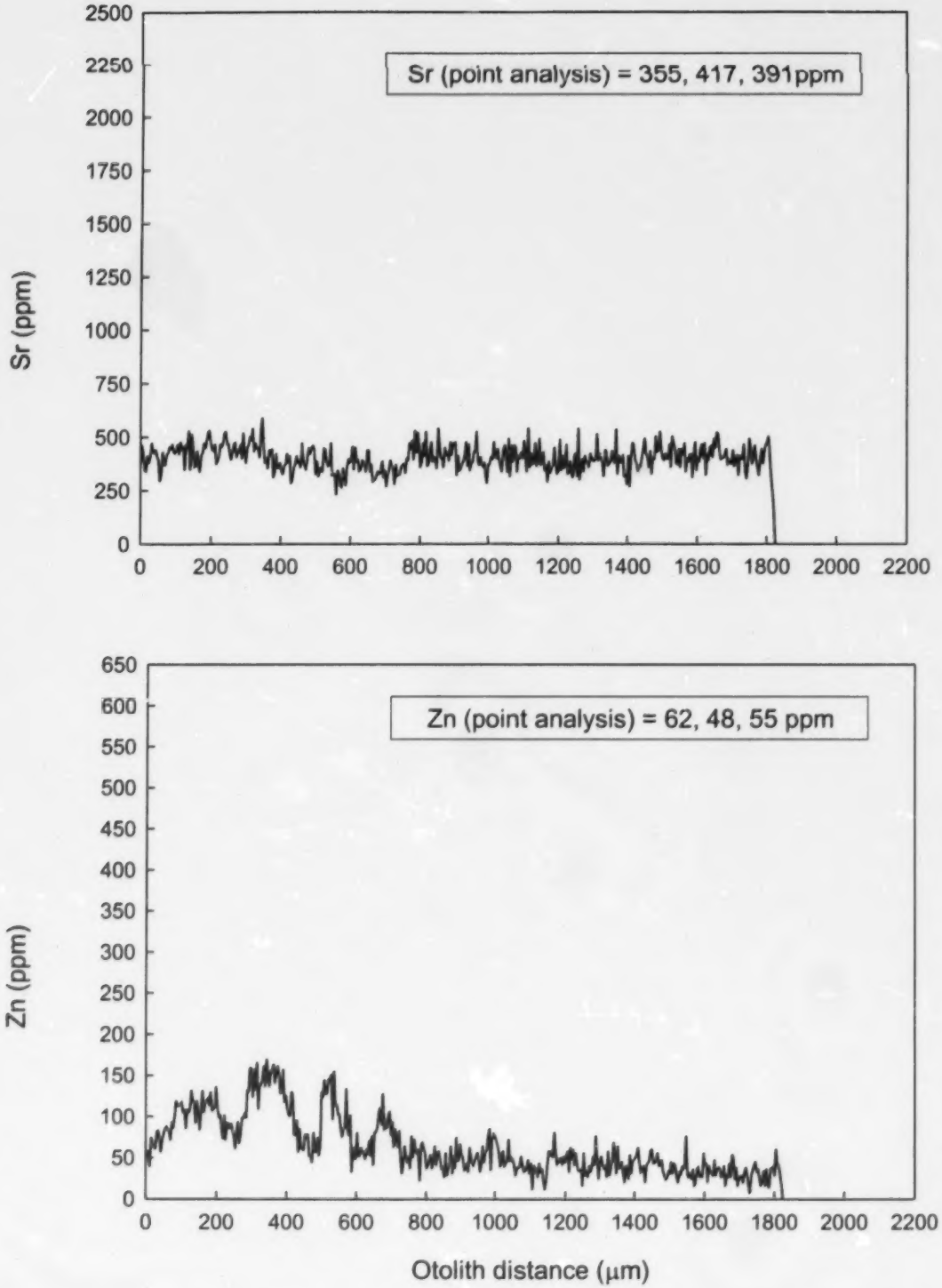

Fig. 59. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (664 mm, 3250 g, male, 21 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

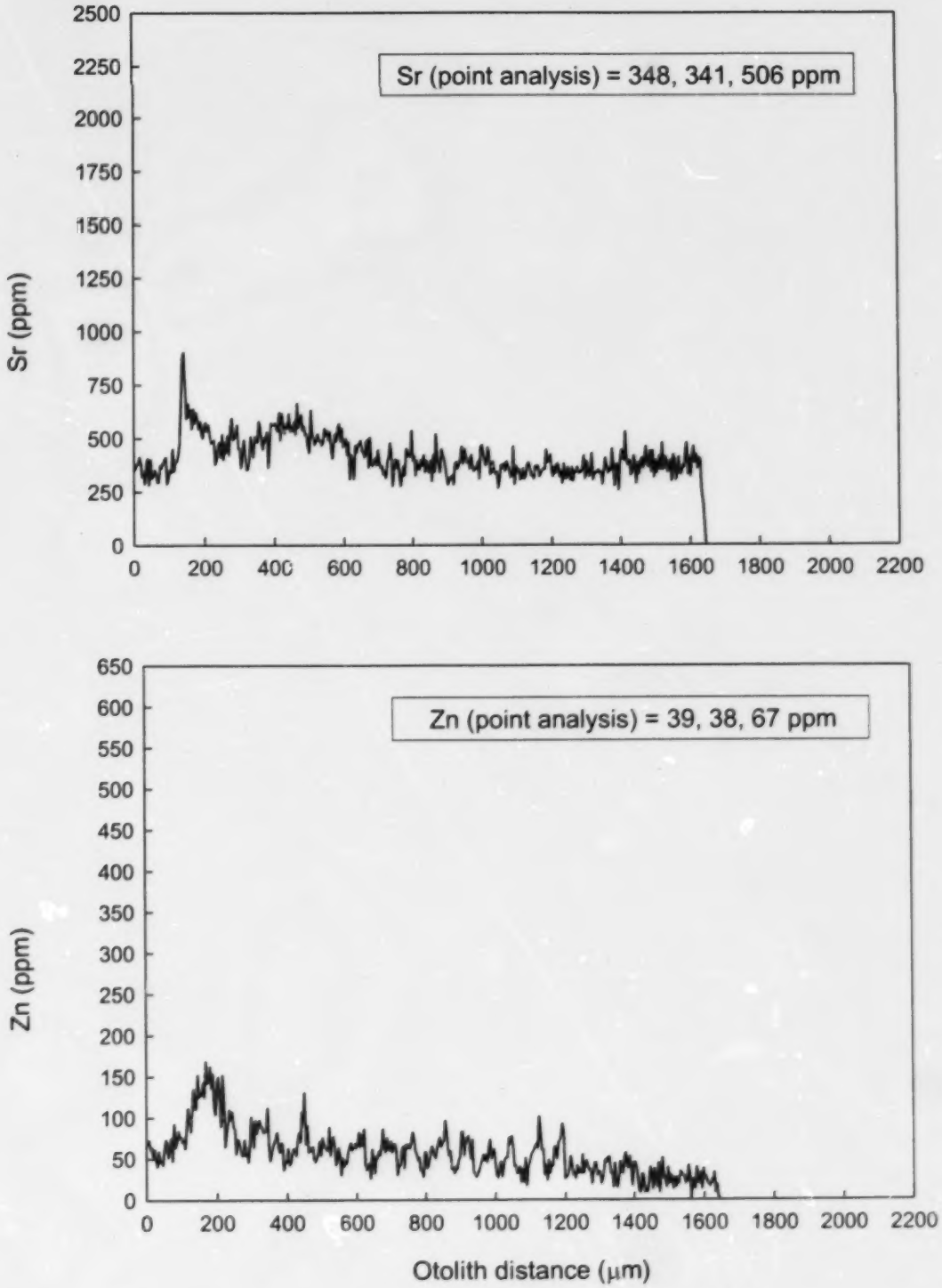

Fig. 60. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (557 mm, 1700 g, male, 21 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

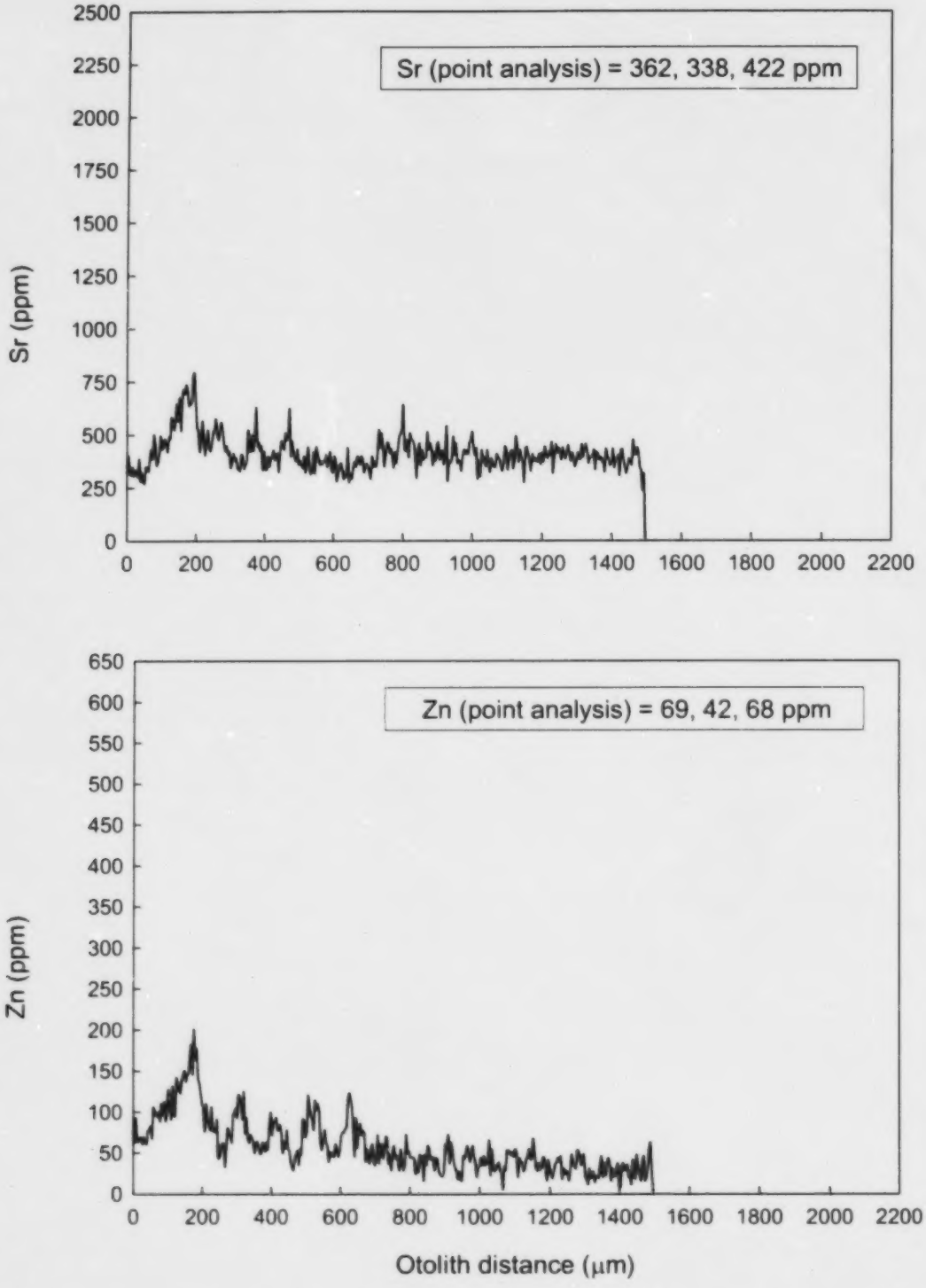

Fig. 61. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (472 mm, 1000 g, female, 18 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

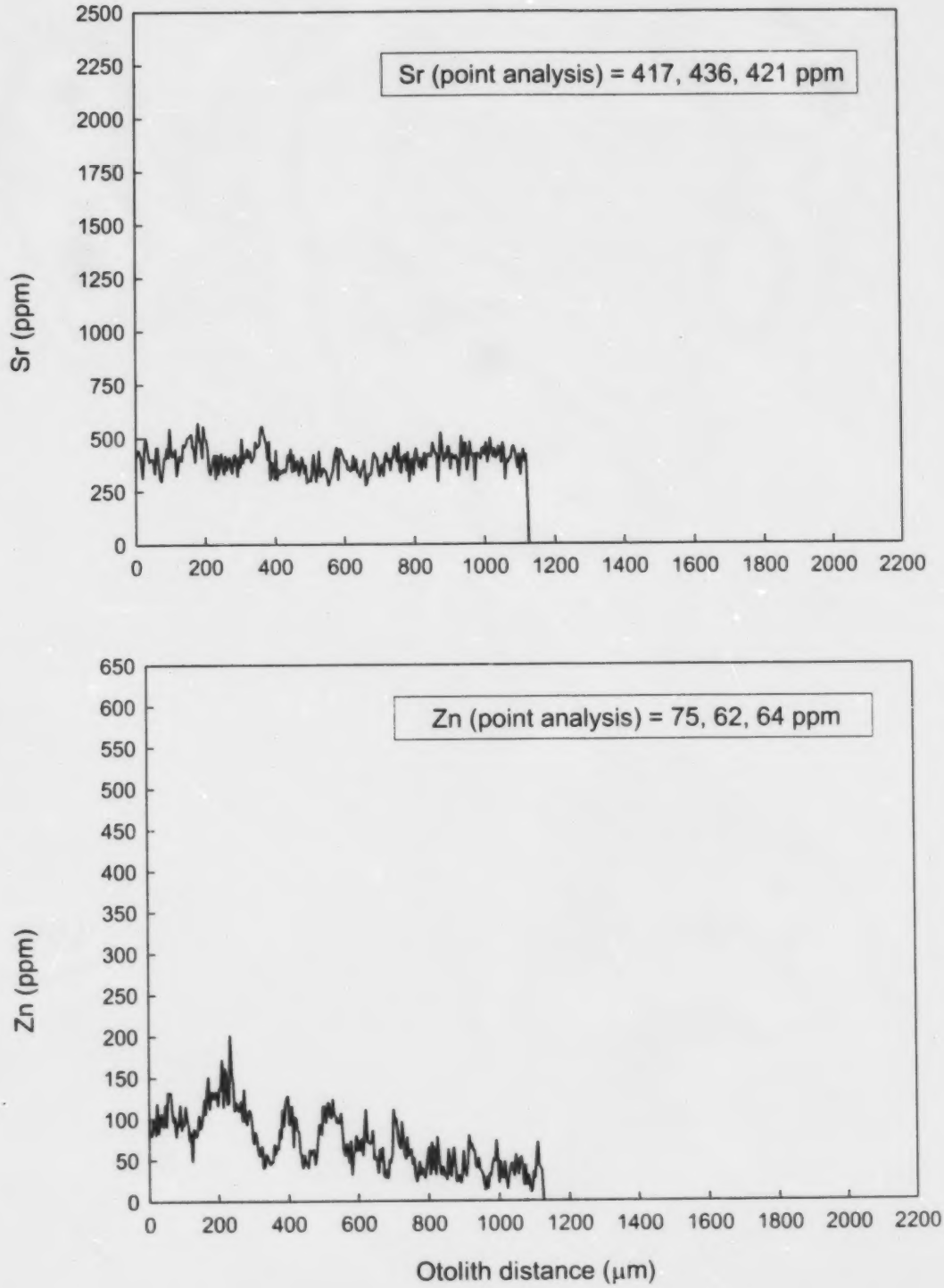

Fig. 62. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (417 mm, 700 g, male, 10 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

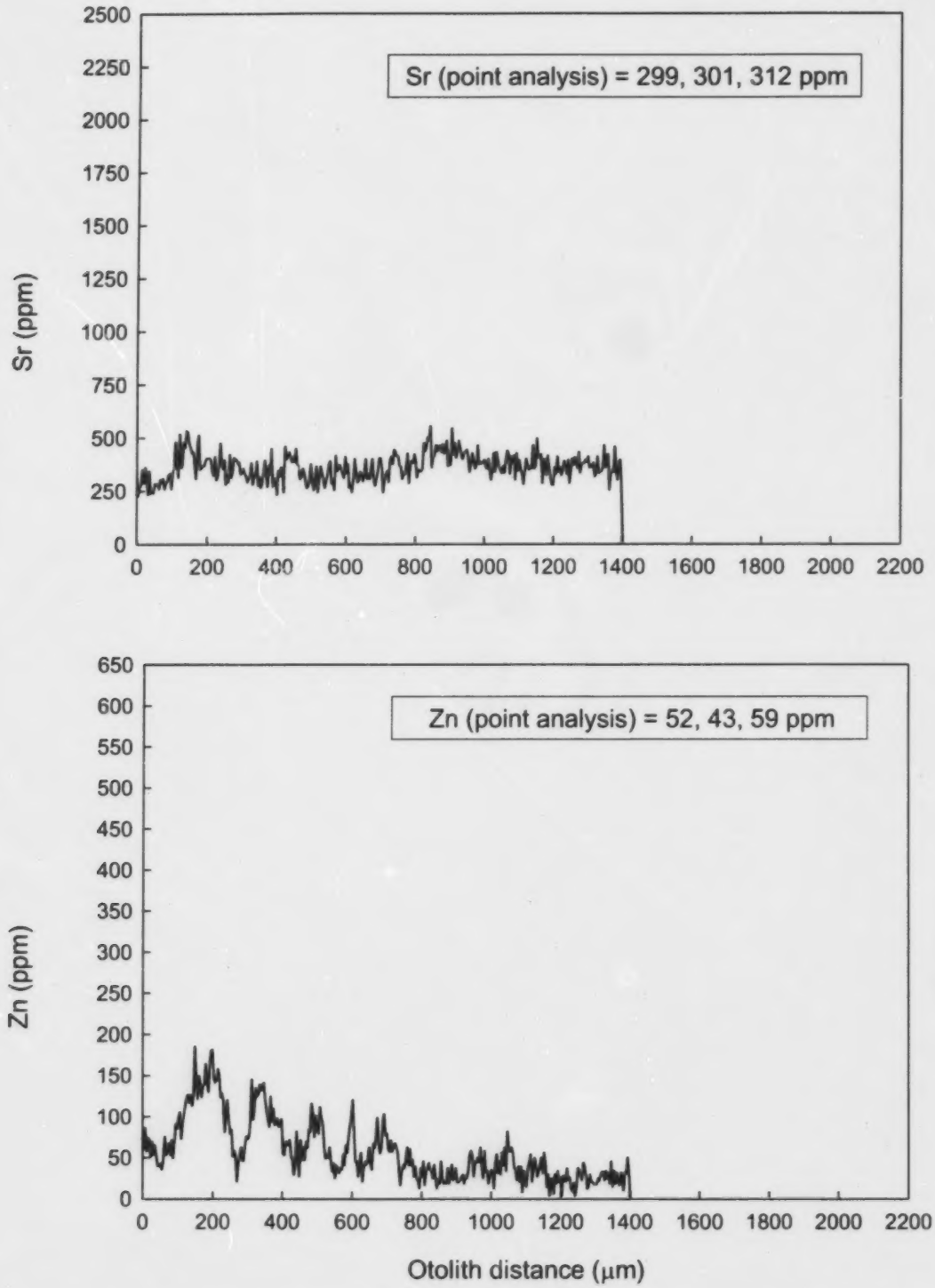

Fig. 63. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (470 mm, 1000 g, female, 14 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

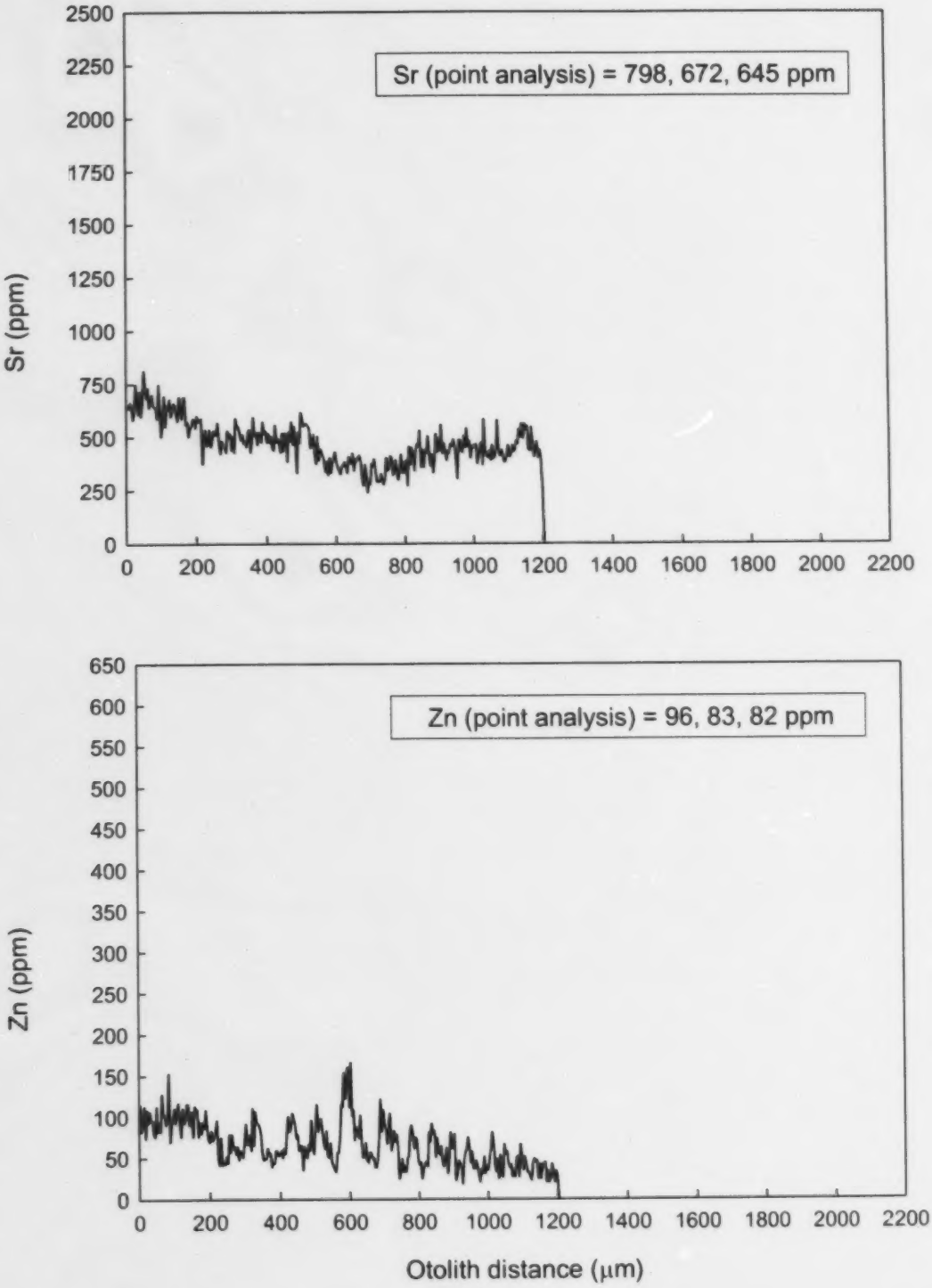

Fig. 64. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (365 mm, 450 g, male, 17 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

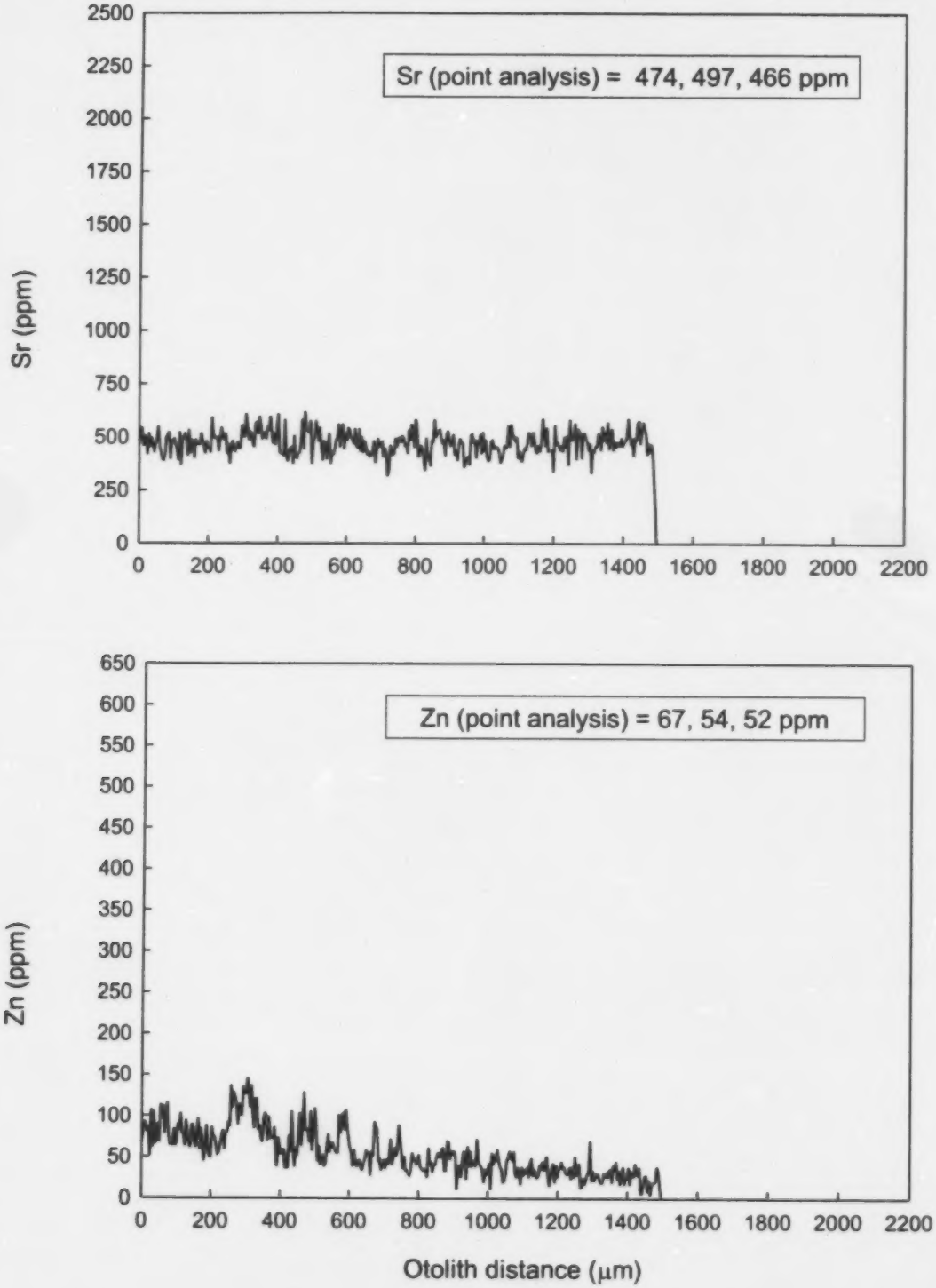

Fig. 65. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (353 mm, 400 g, male, 21 yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

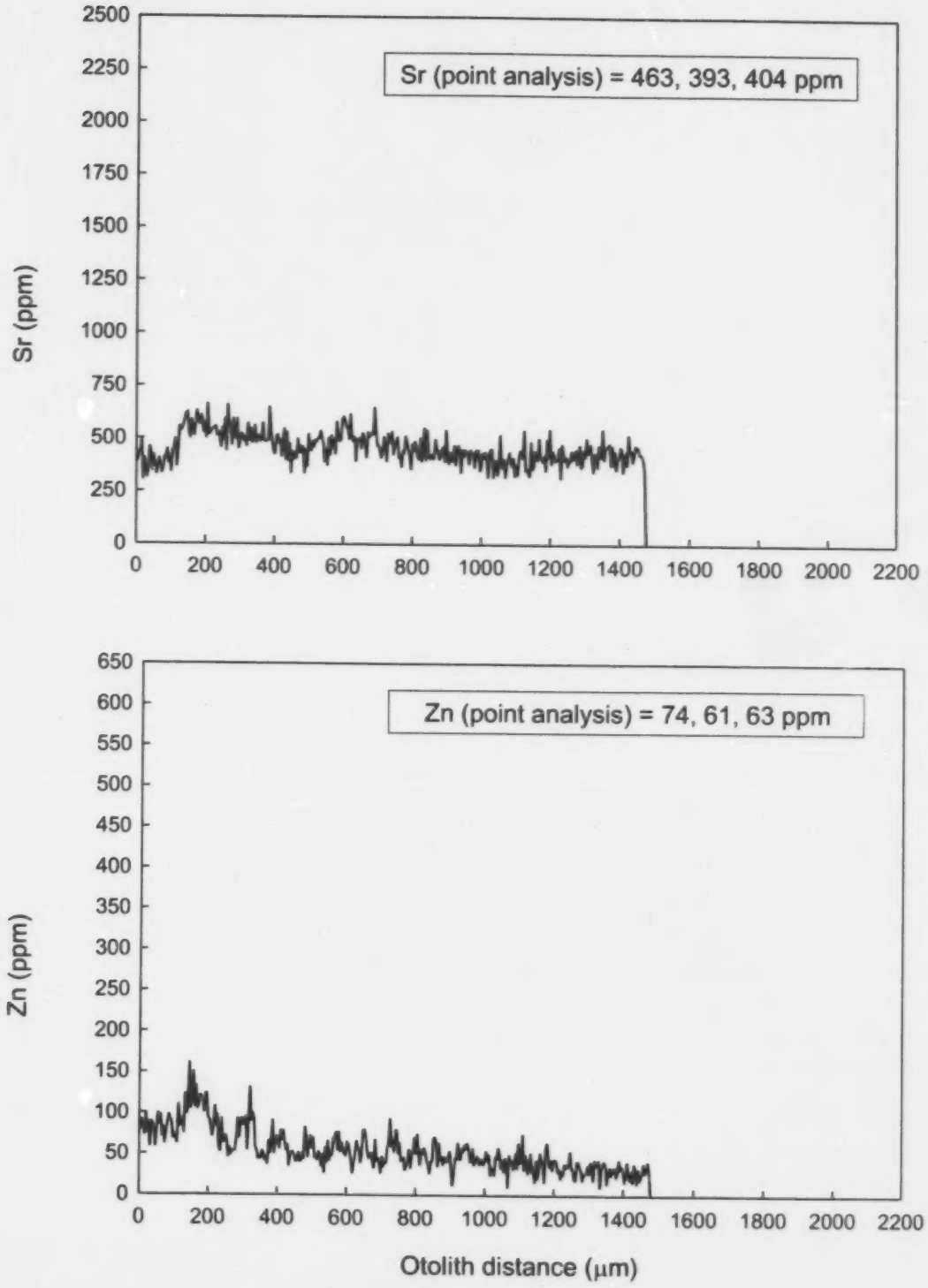

Fig. 66. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (435 mm, 725 g, male, 18yr) caught in Lake Hazen, August 1981. Point analysis results are also indicated.

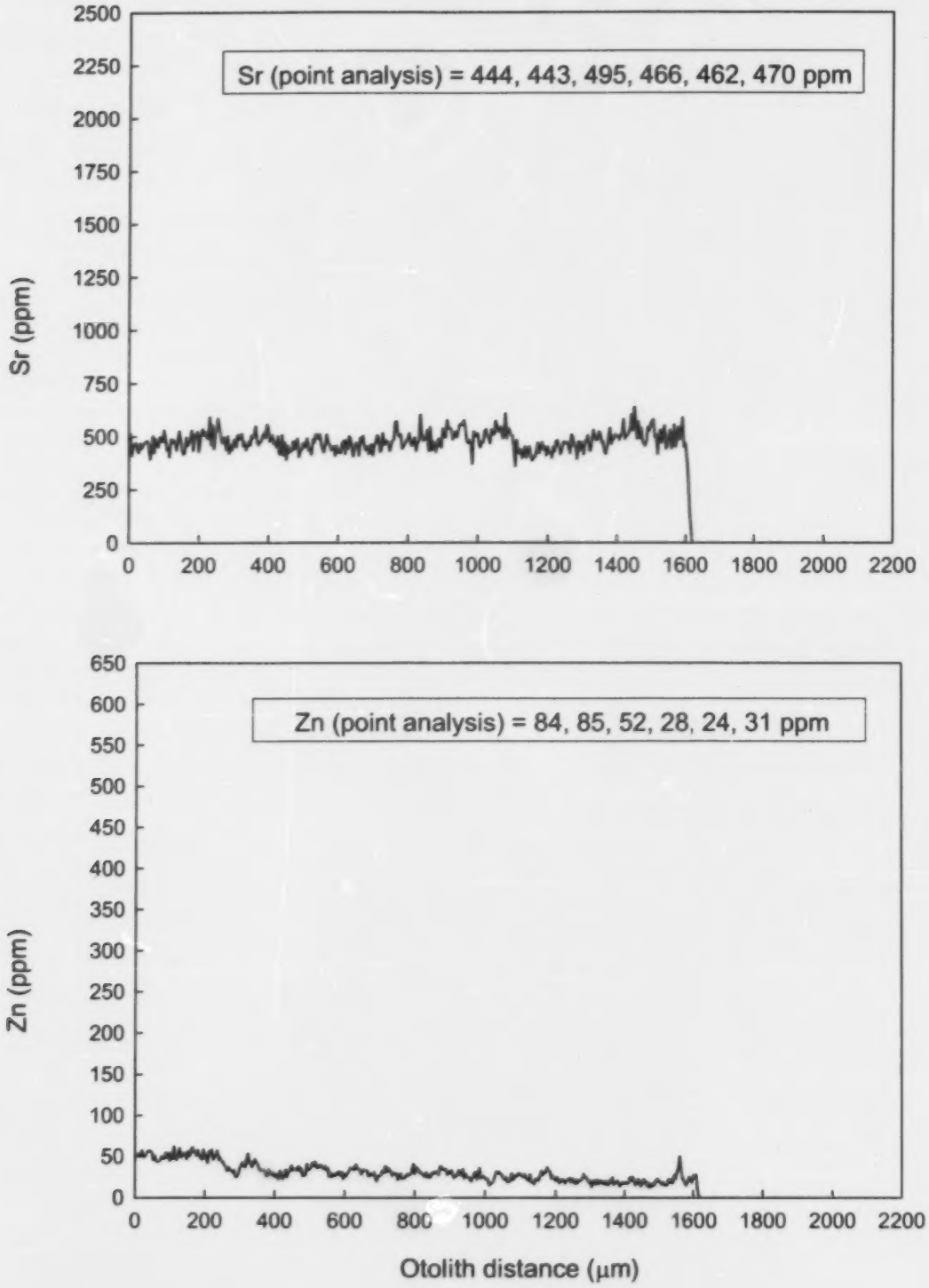

Fig. 67. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a small-form Arctic char (357 mm, 333 g, male, 22 yr) caught in Lake Hazen, May 1990. Point analysis results are also indicated.

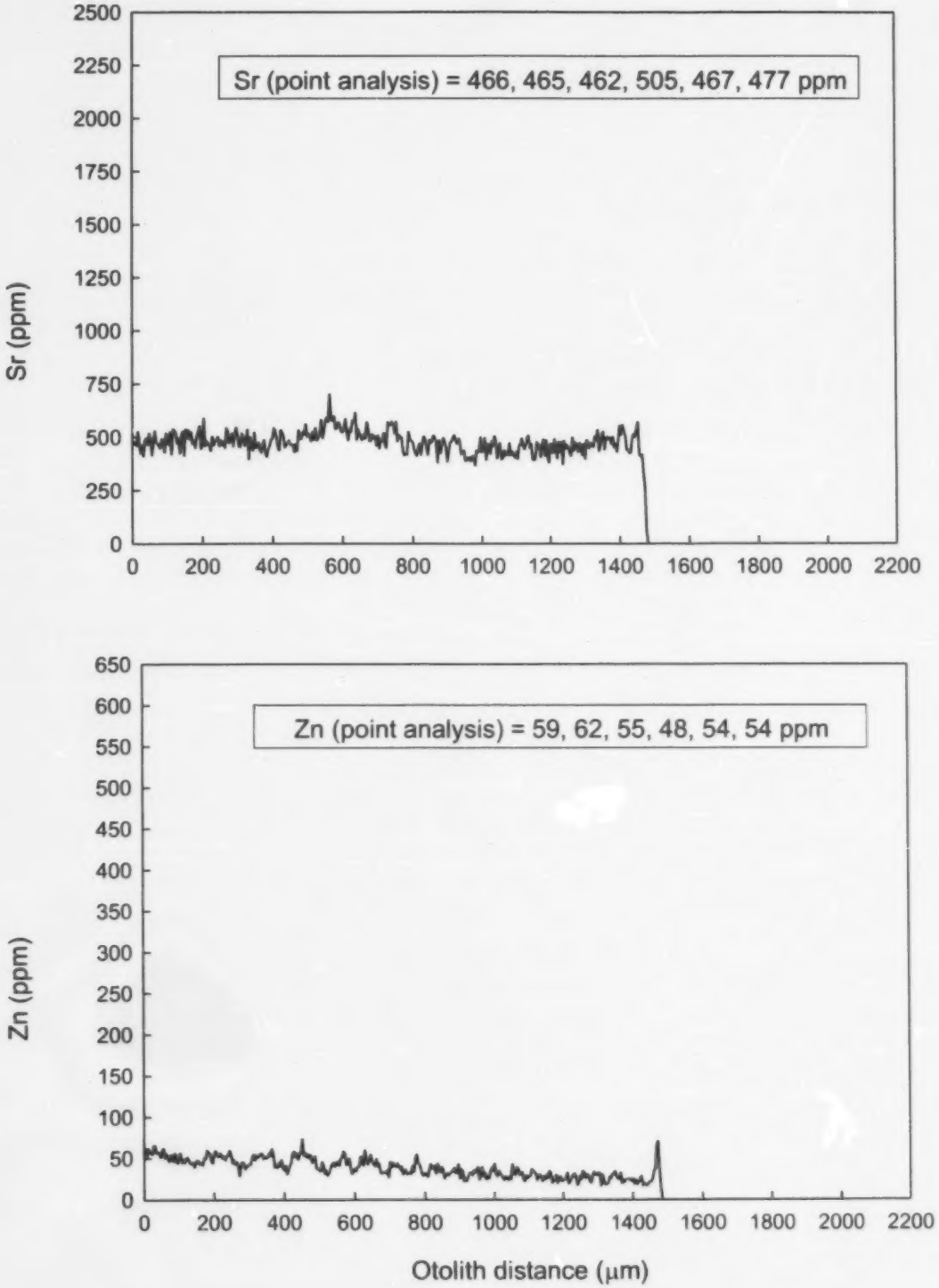

Fig. 68. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a small-form Arctic char (348 mm, 416 g, female, 26 yr) caught in Lake Hazen, May 1990. Point analysis results are also indicated.

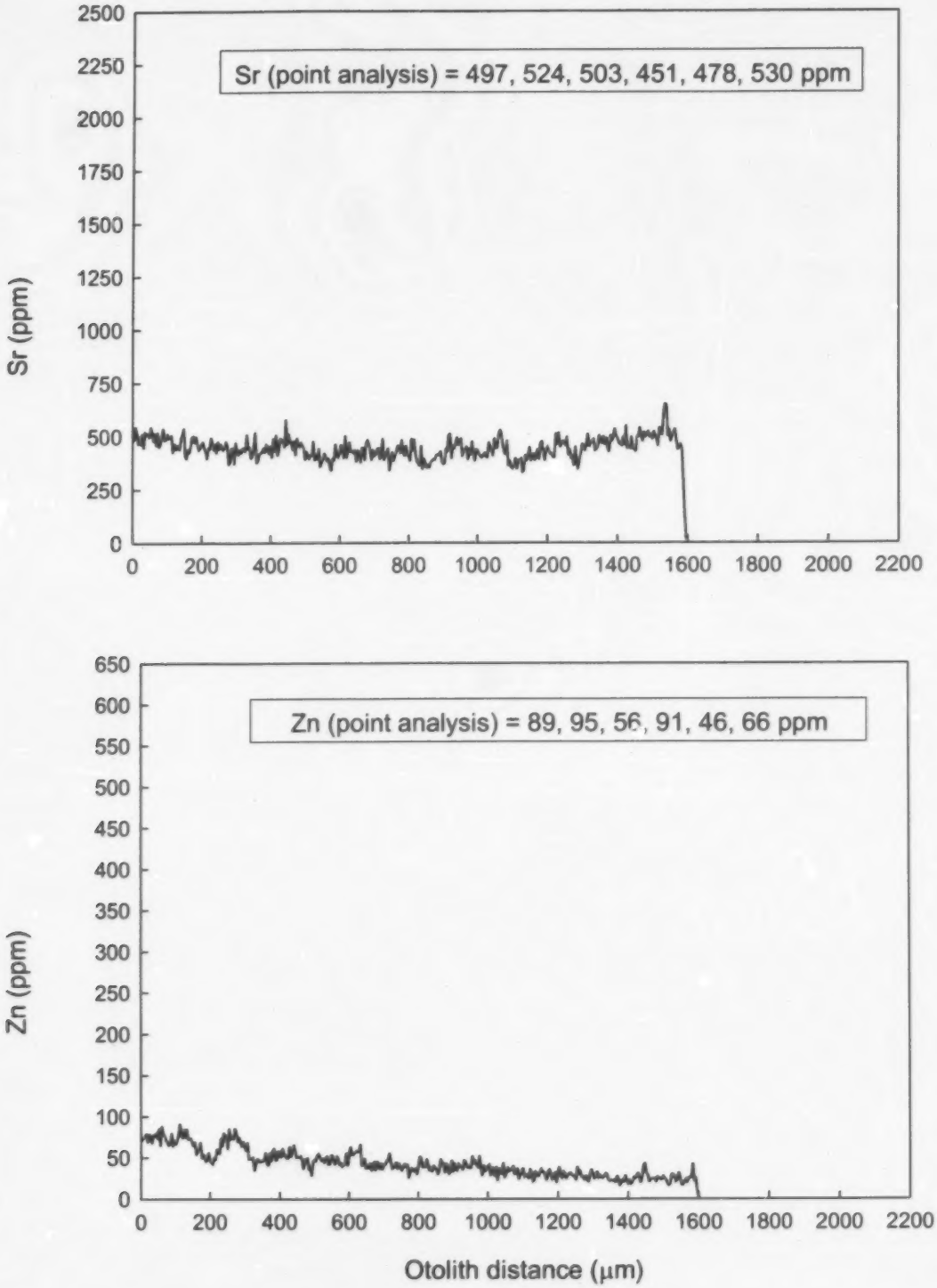

Fig. 69. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a small-form Arctic char (326 mm, 365 g, male, 19 yr) caught in Lake Hazen, May 1990. Point analysis results are also indicated.

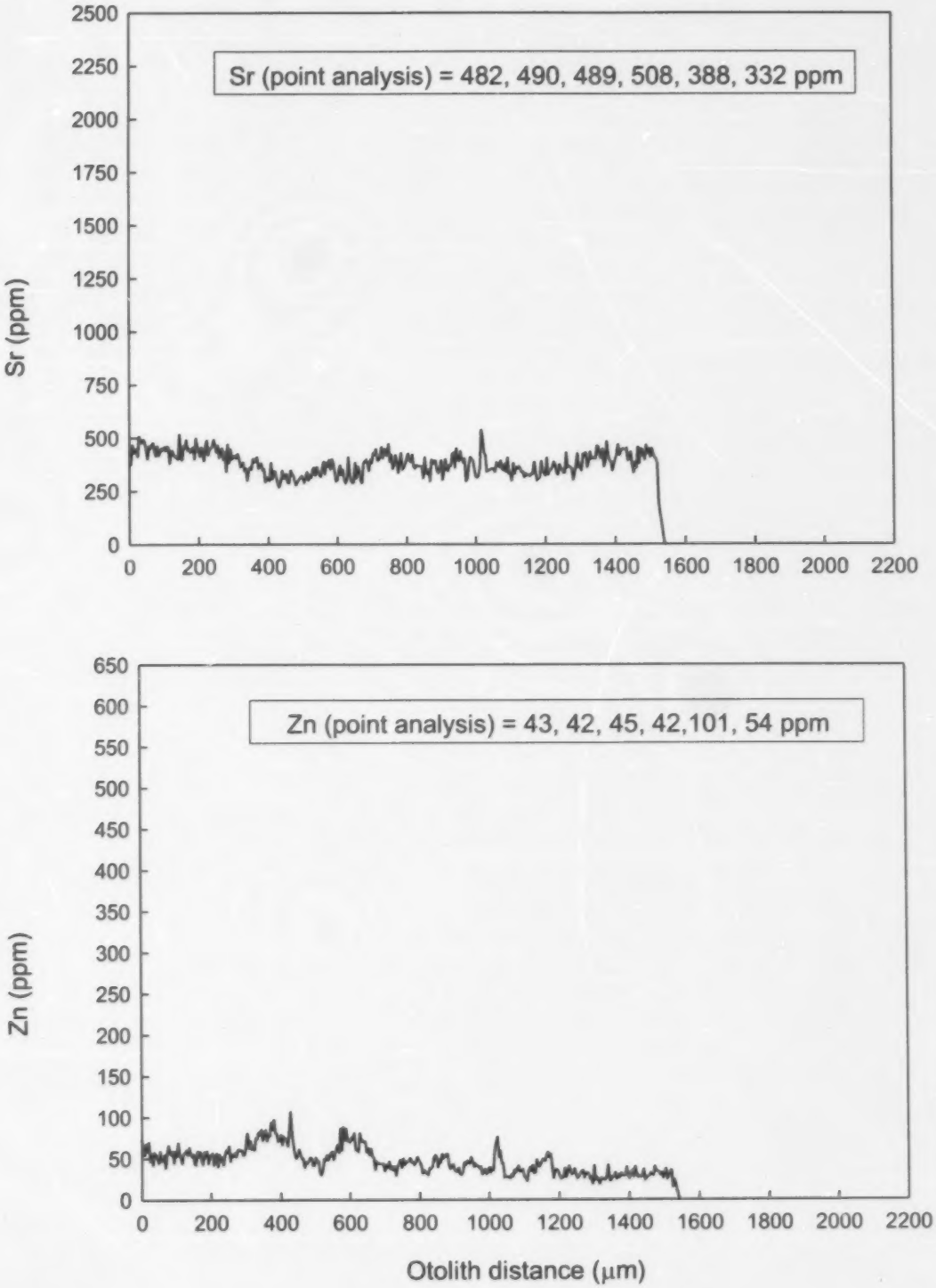

Fig. 70. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a small-form Arctic char (328 mm, 347 g, female, 21 yr) Caught in Lake Hazen, May 1990. Point analysis results are also indicated.

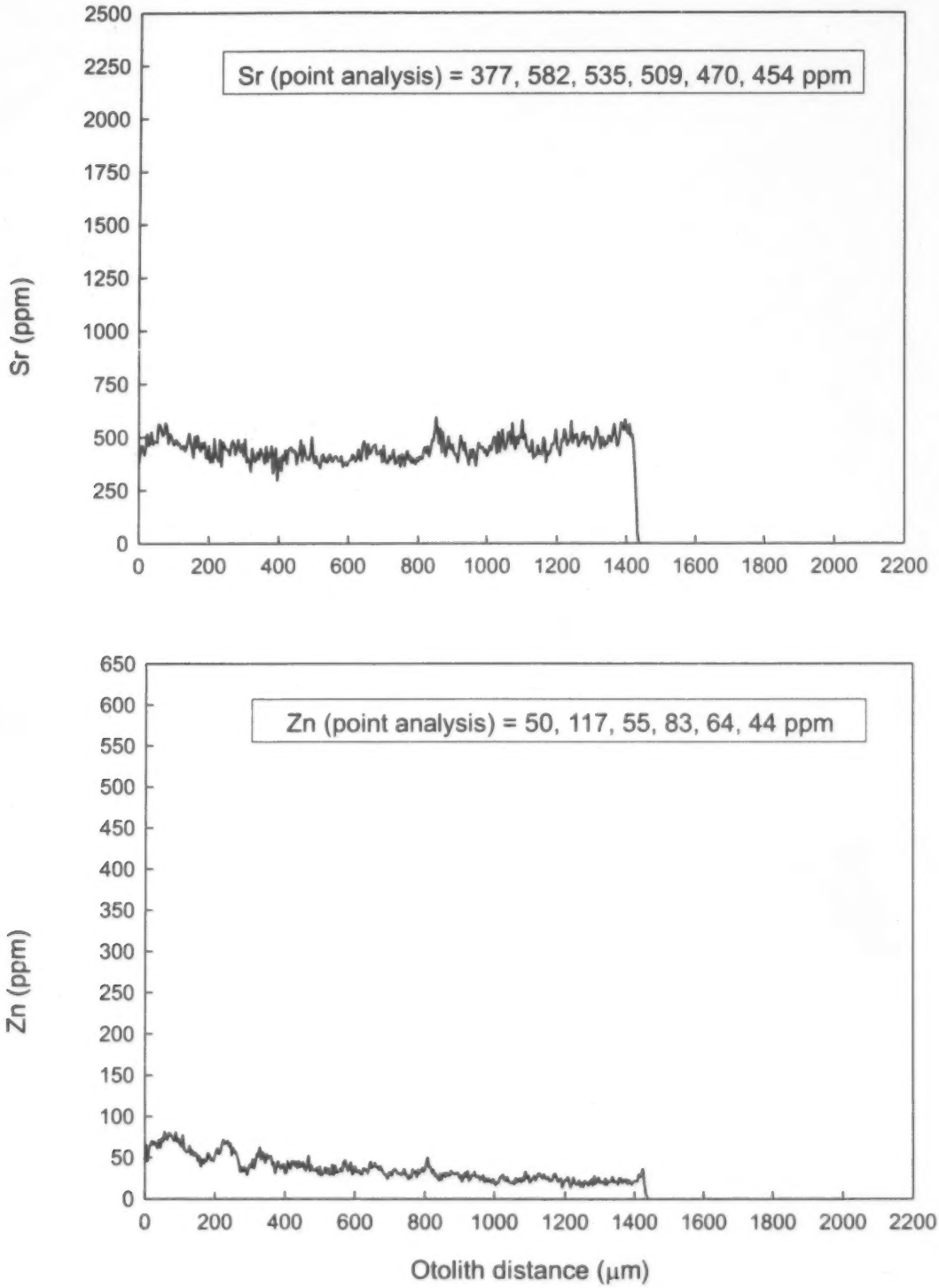

Fig. 71. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a small-form Arctic char (362 mm, 448 g, male, 22 yr) caught in Lake Hazen, May 1990. Point analysis results are also indicated.

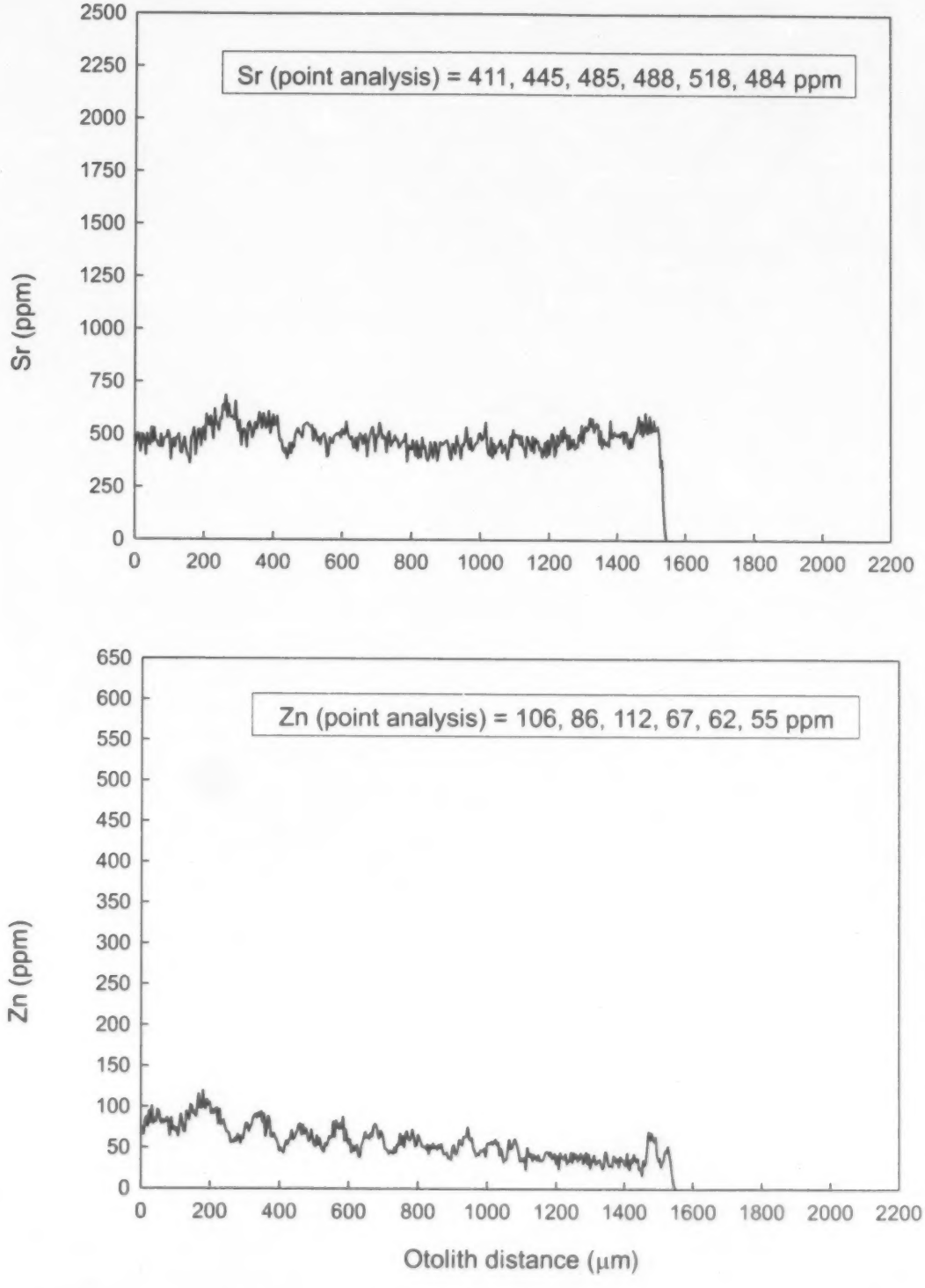

Fig. 72. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a small-form Arctic char (370 mm, 482 g, male, 22 yr) caught in Lake Hazen, May 1990. Point analysis results are also indicated.

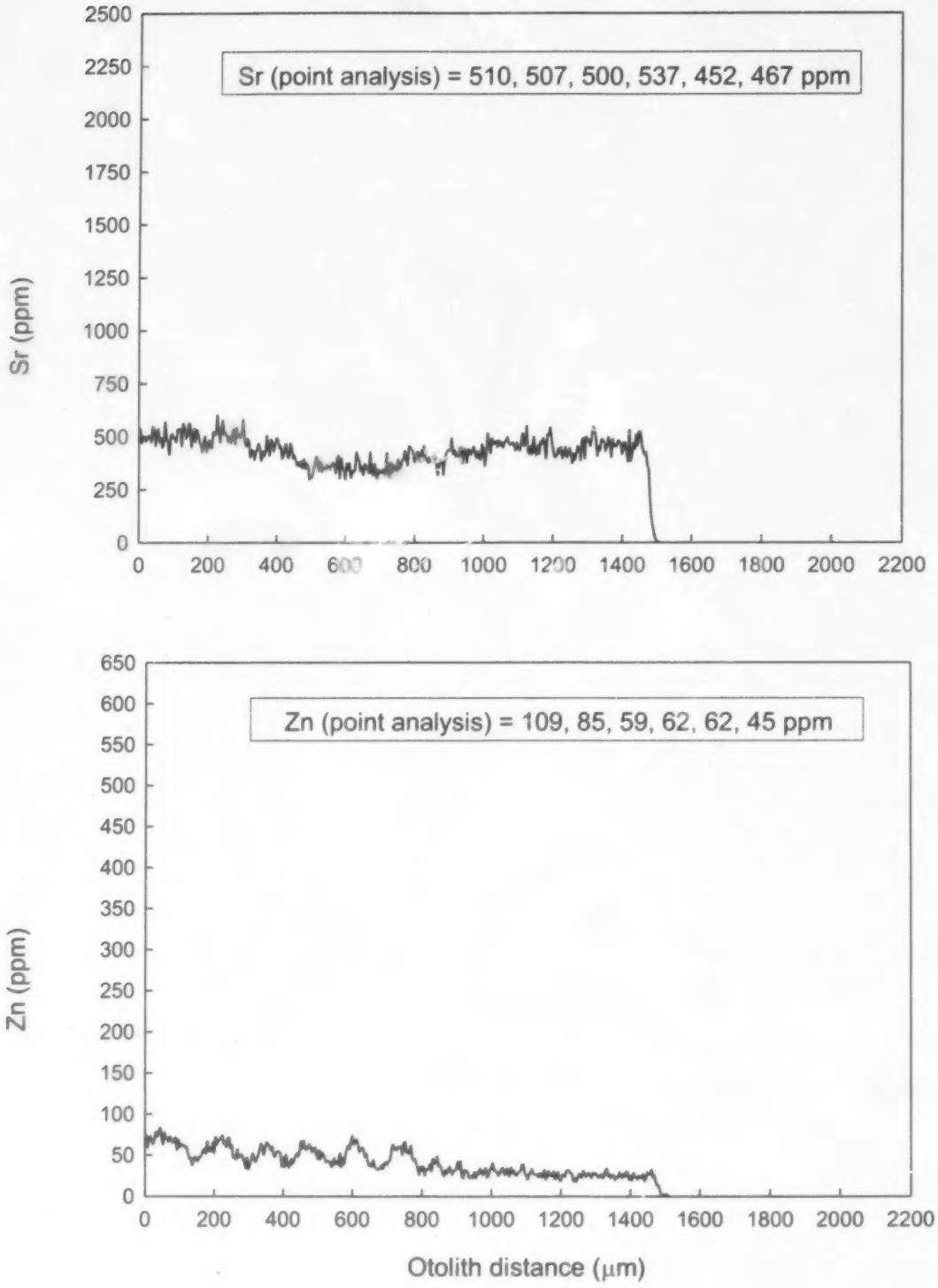

Fig. 73. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a small-form Arctic char (391 mm, 533 g, male, 23 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

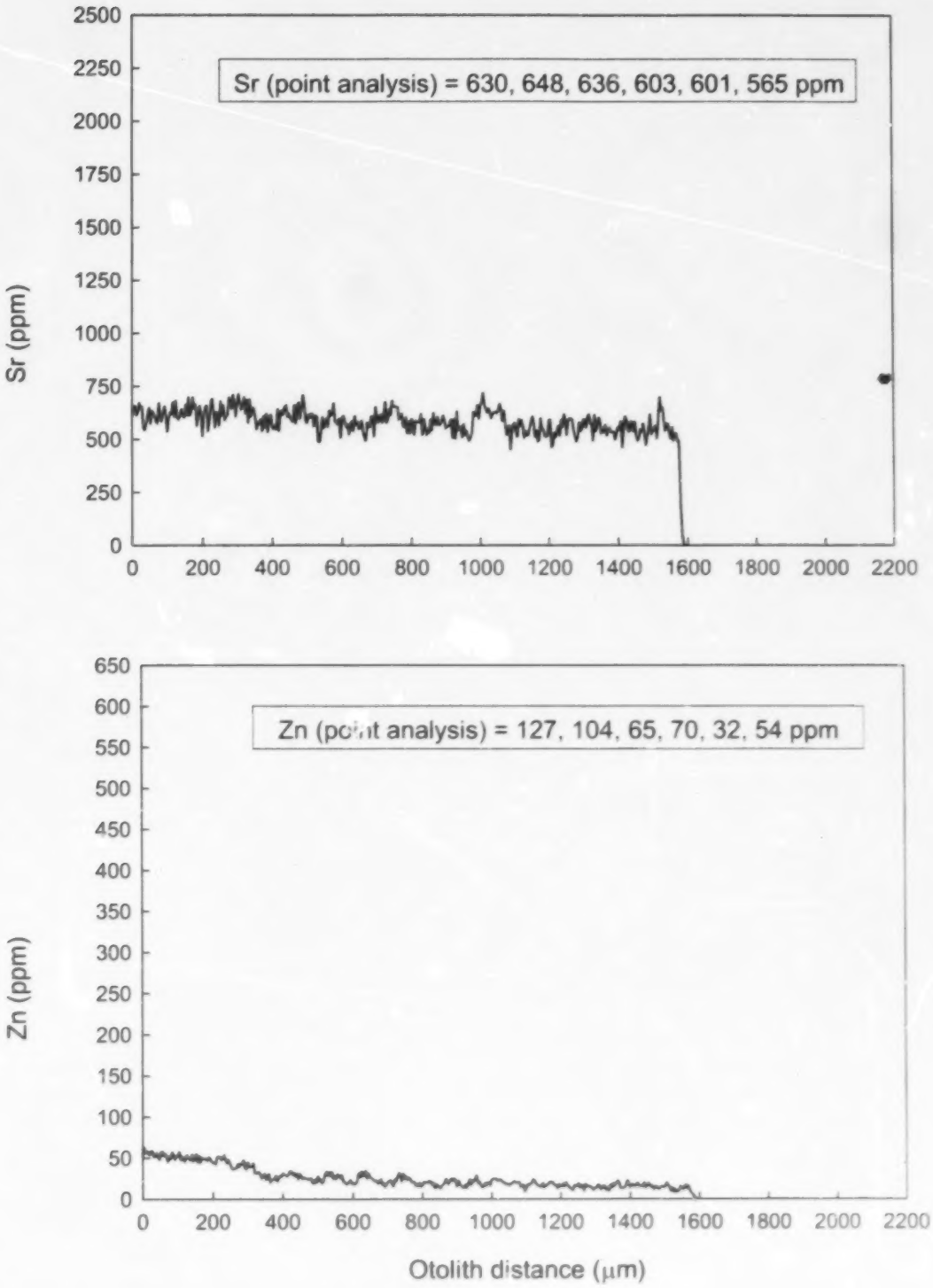

Fig. 74. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a small-form Arctic char (362 mm, 483 g, male, 25 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

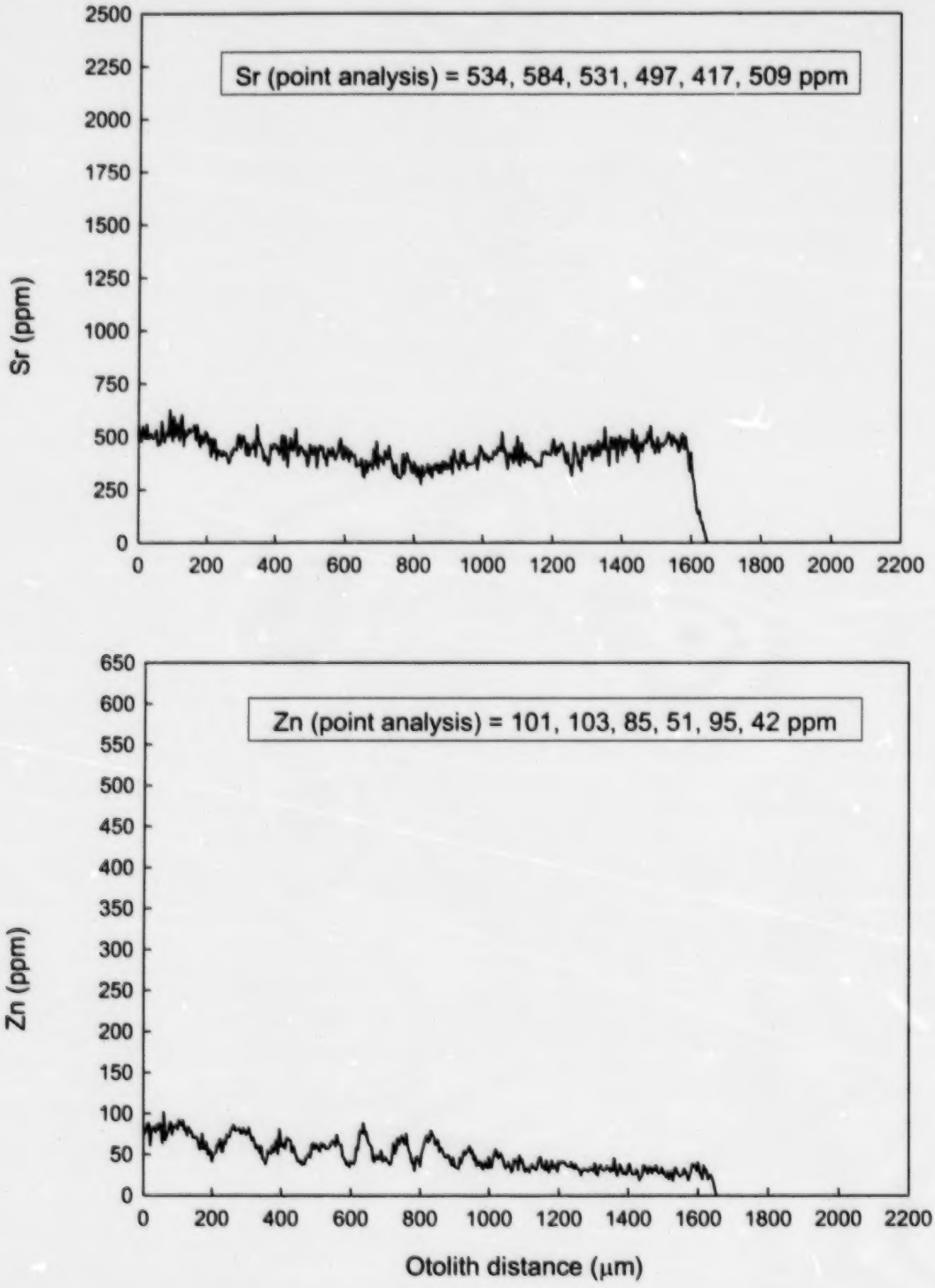

Fig. 75. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a small-form Arctic char (366 mm, 472 g, male, 24 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

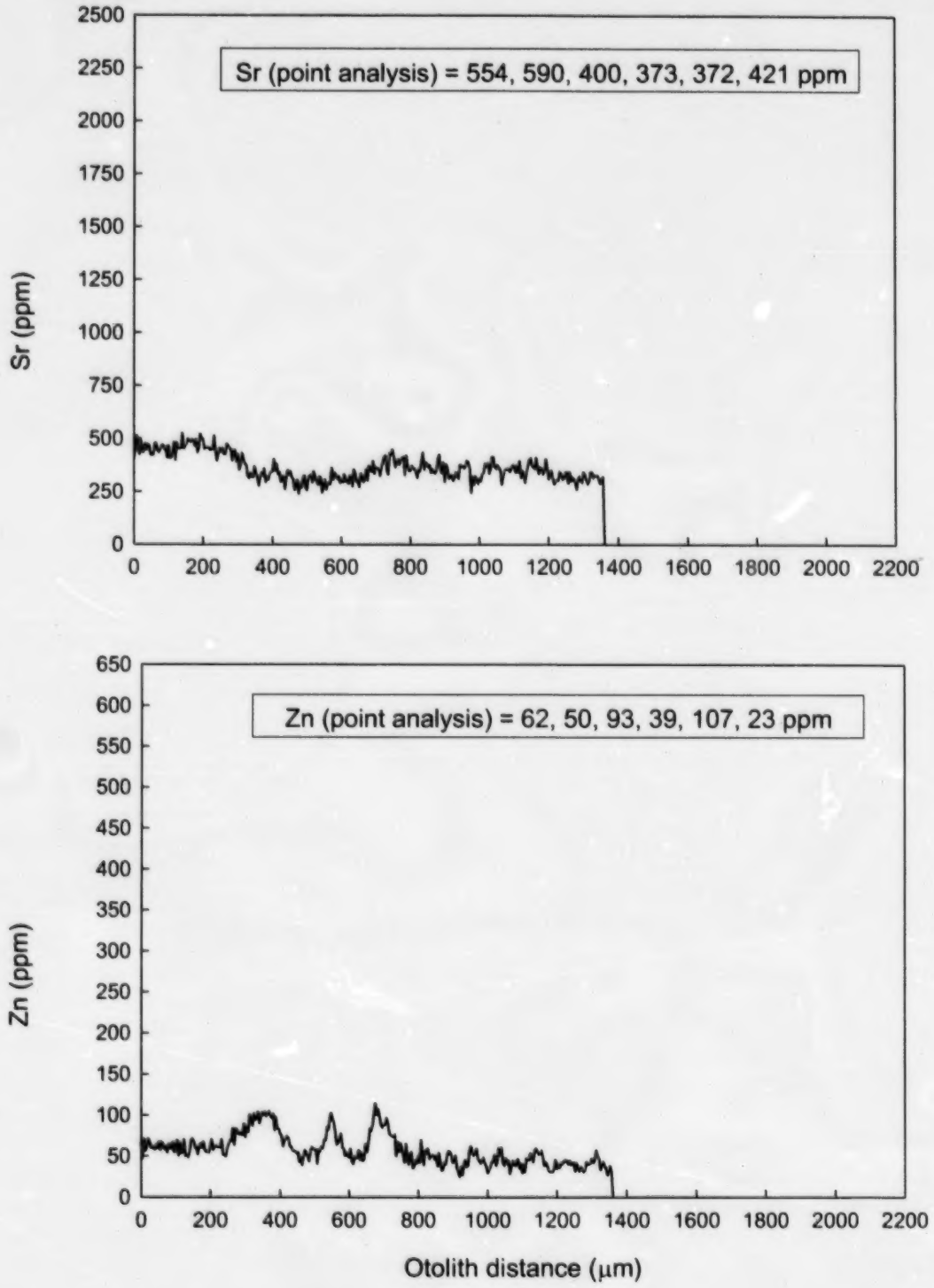

Fig. 76. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (611 mm, 2170 g, male, 22 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

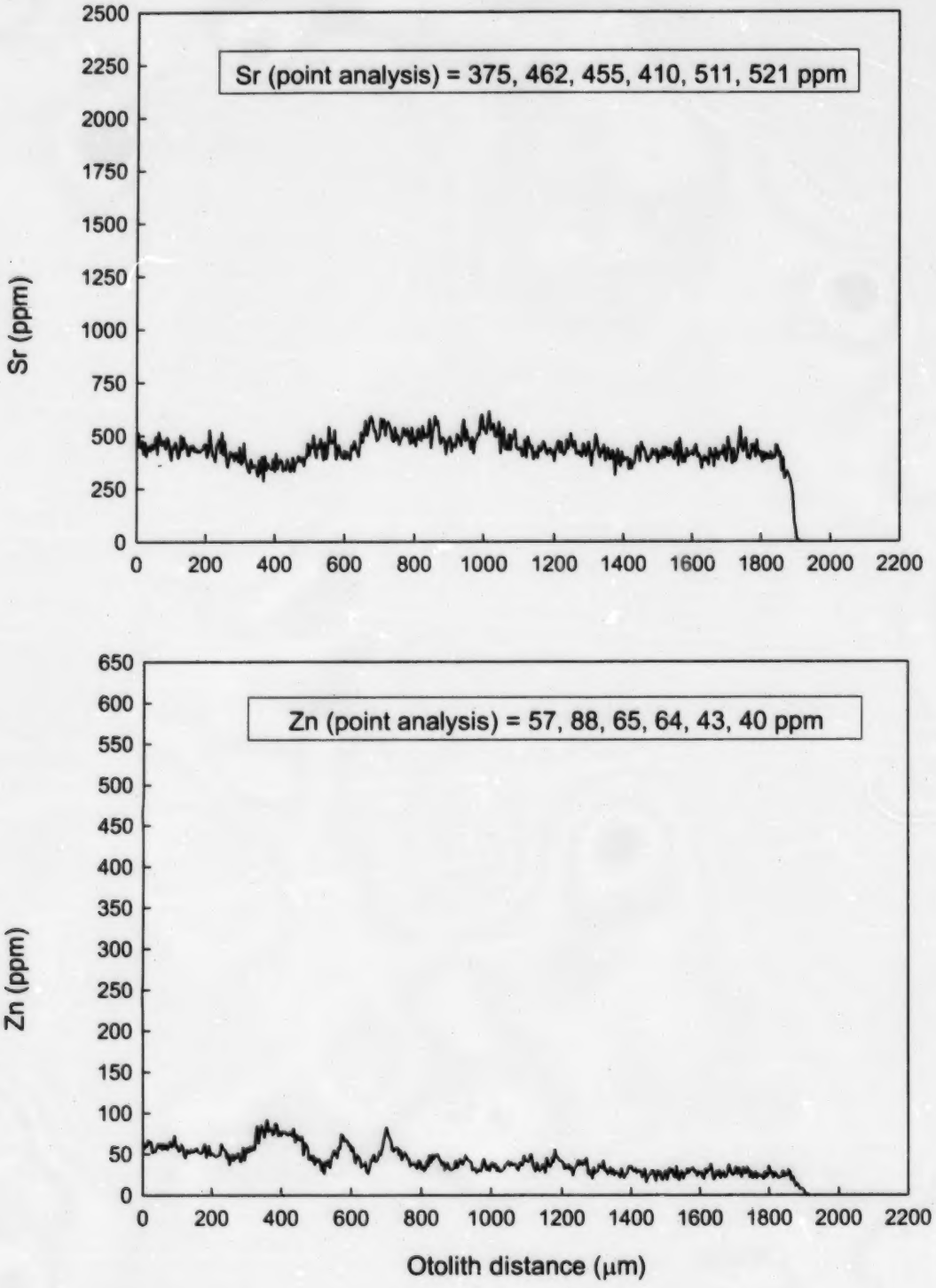

Fig. 77. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (635 mm, 2216 g, male, 24 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

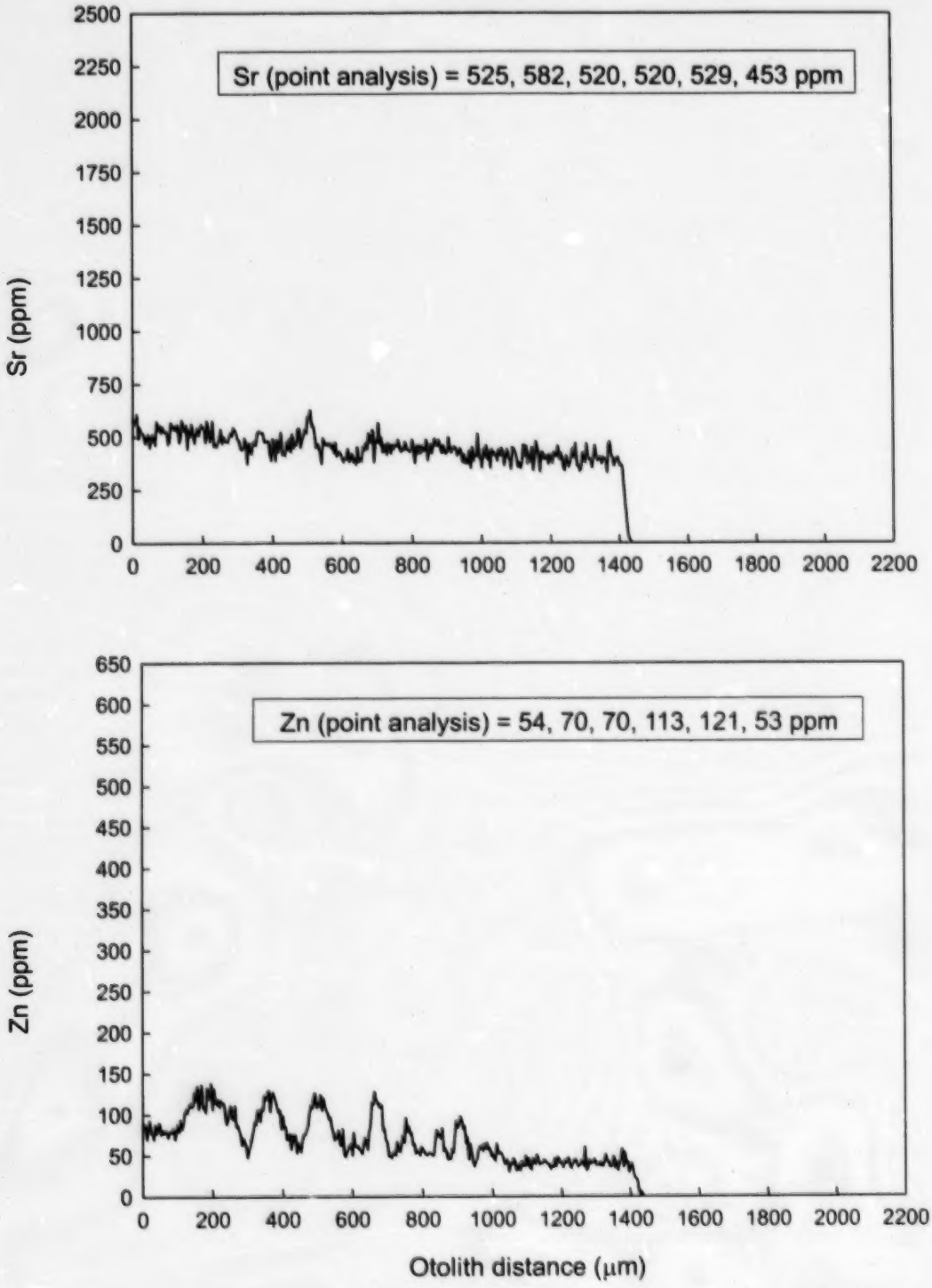

Fig. 78. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (478 mm, 979 g, female, 22 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

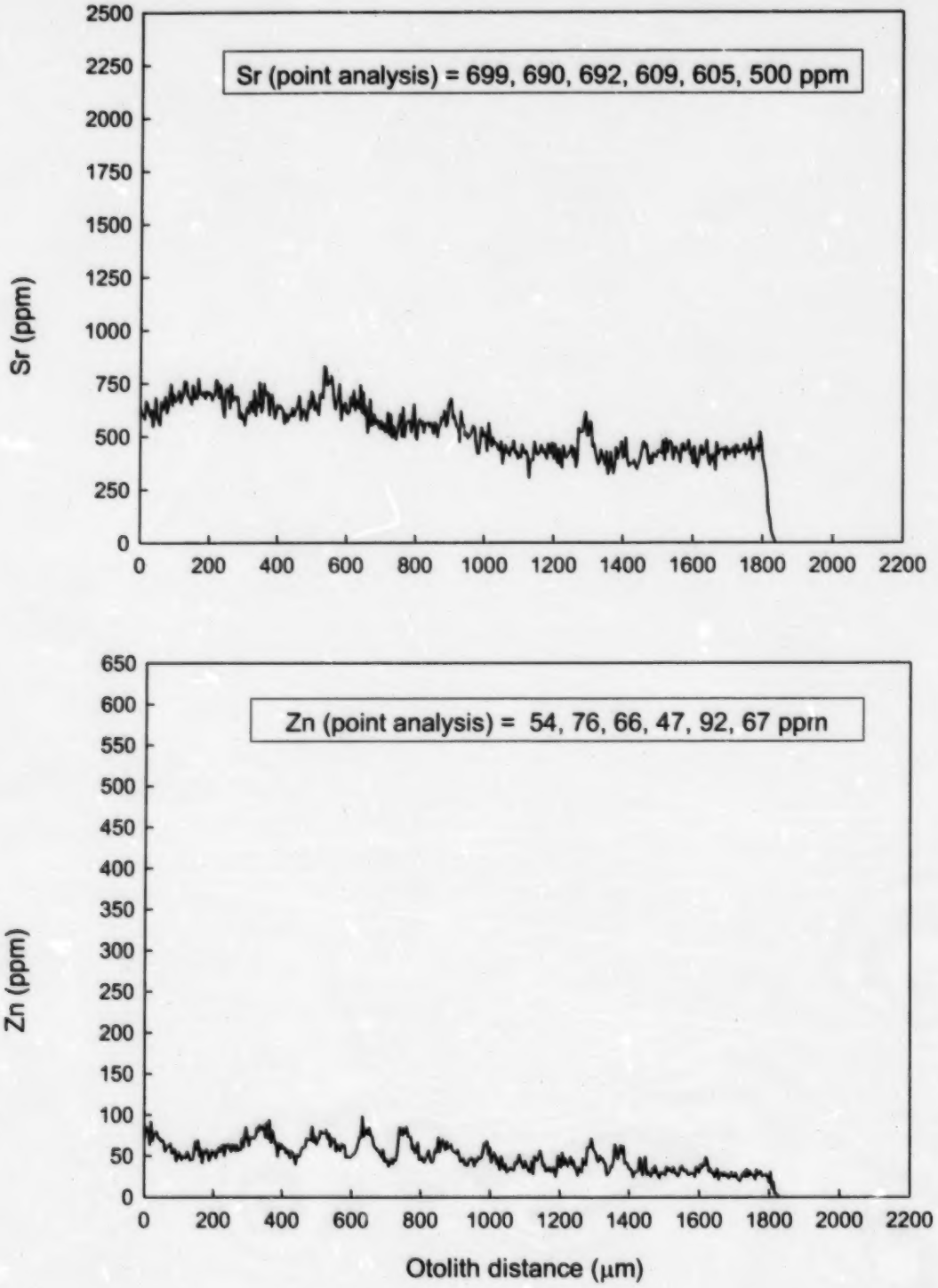

Fig. 79. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (578 mm, 1956 g, male, 21 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

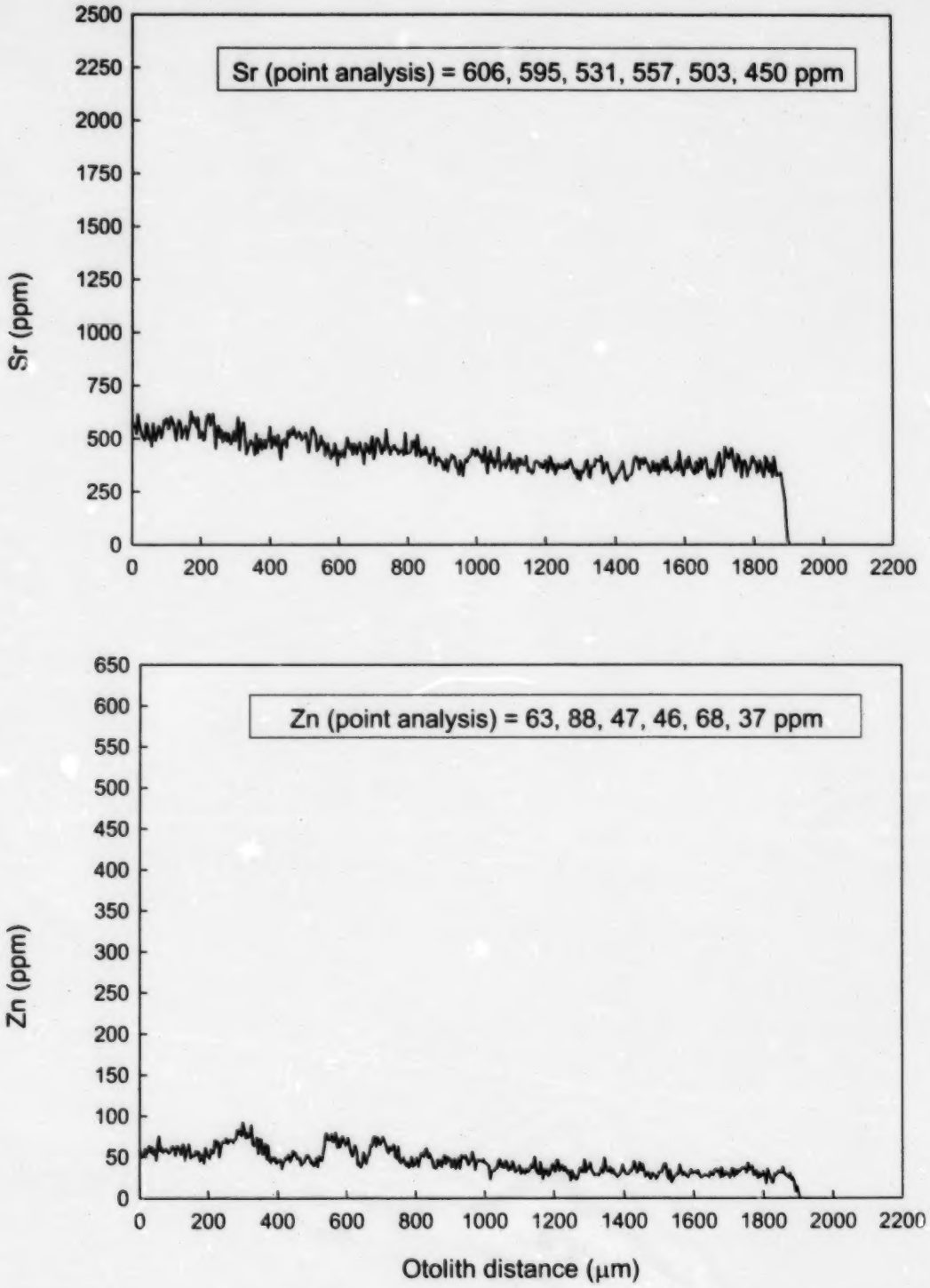

Fig. 80. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (618 mm, 2050 g, male, 24 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

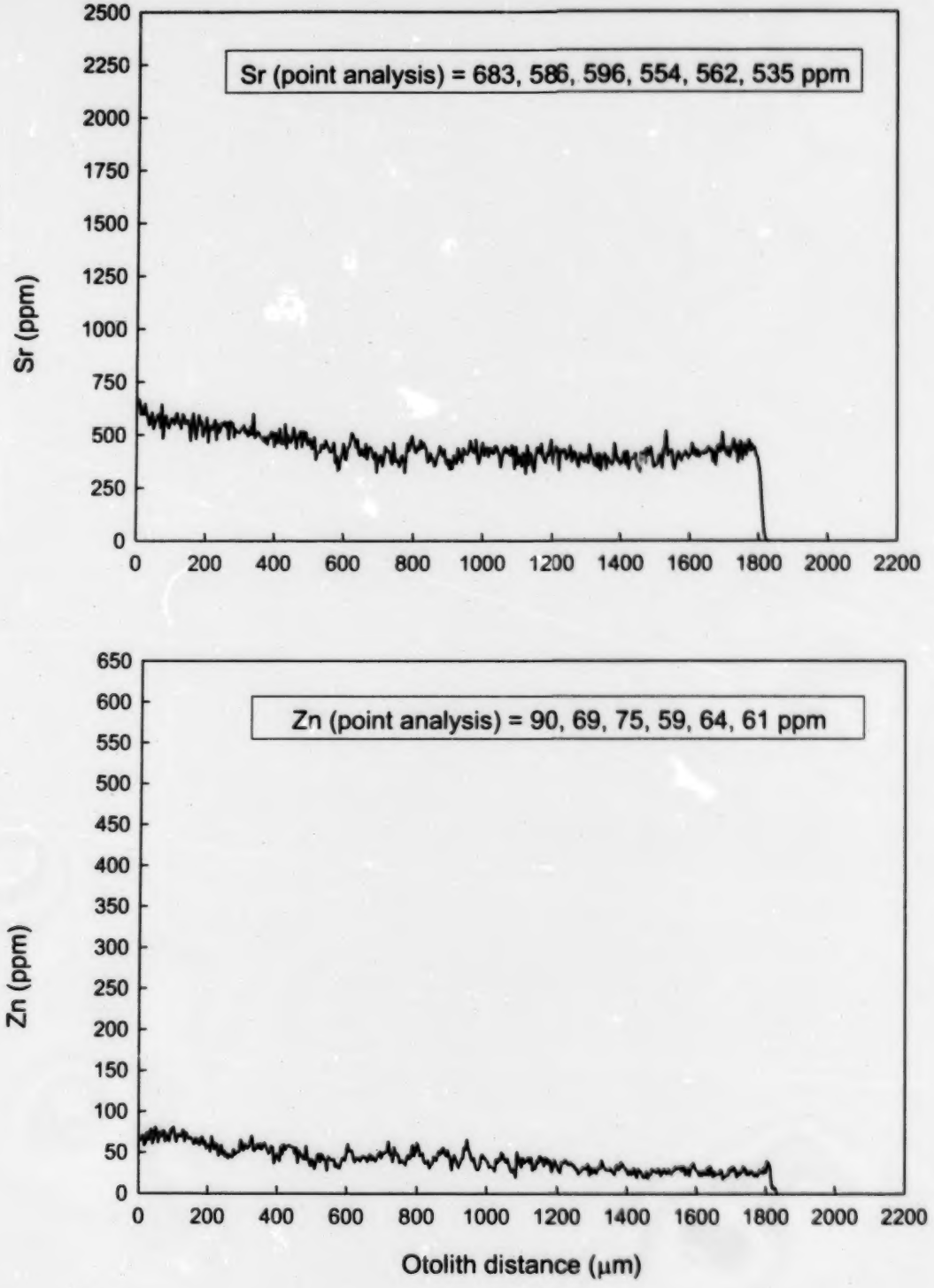

Fig. 81. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (570 mm, 1768 g, male, 27 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

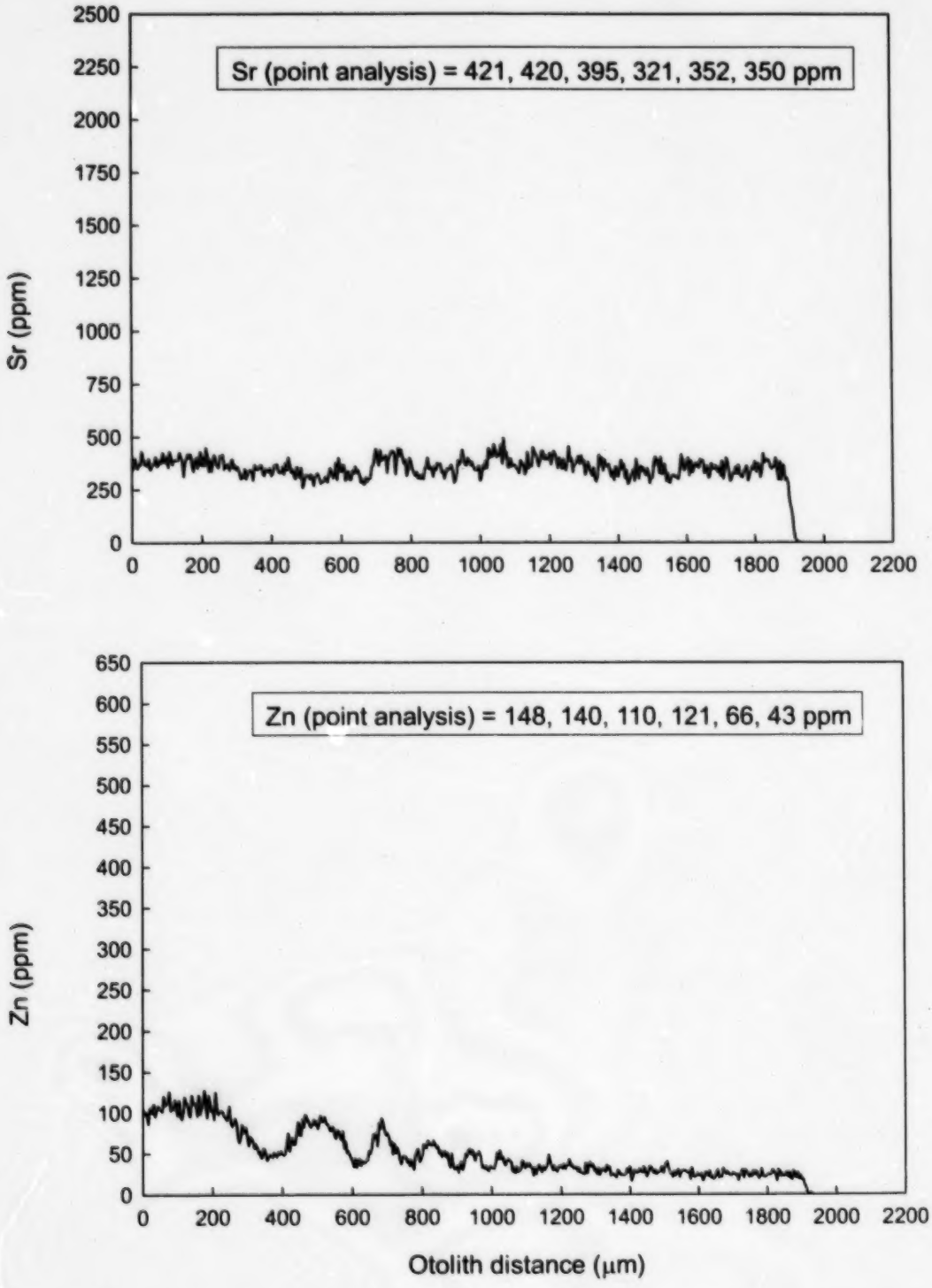

Fig. 82. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (560 mm, 1733 g, male, 27 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

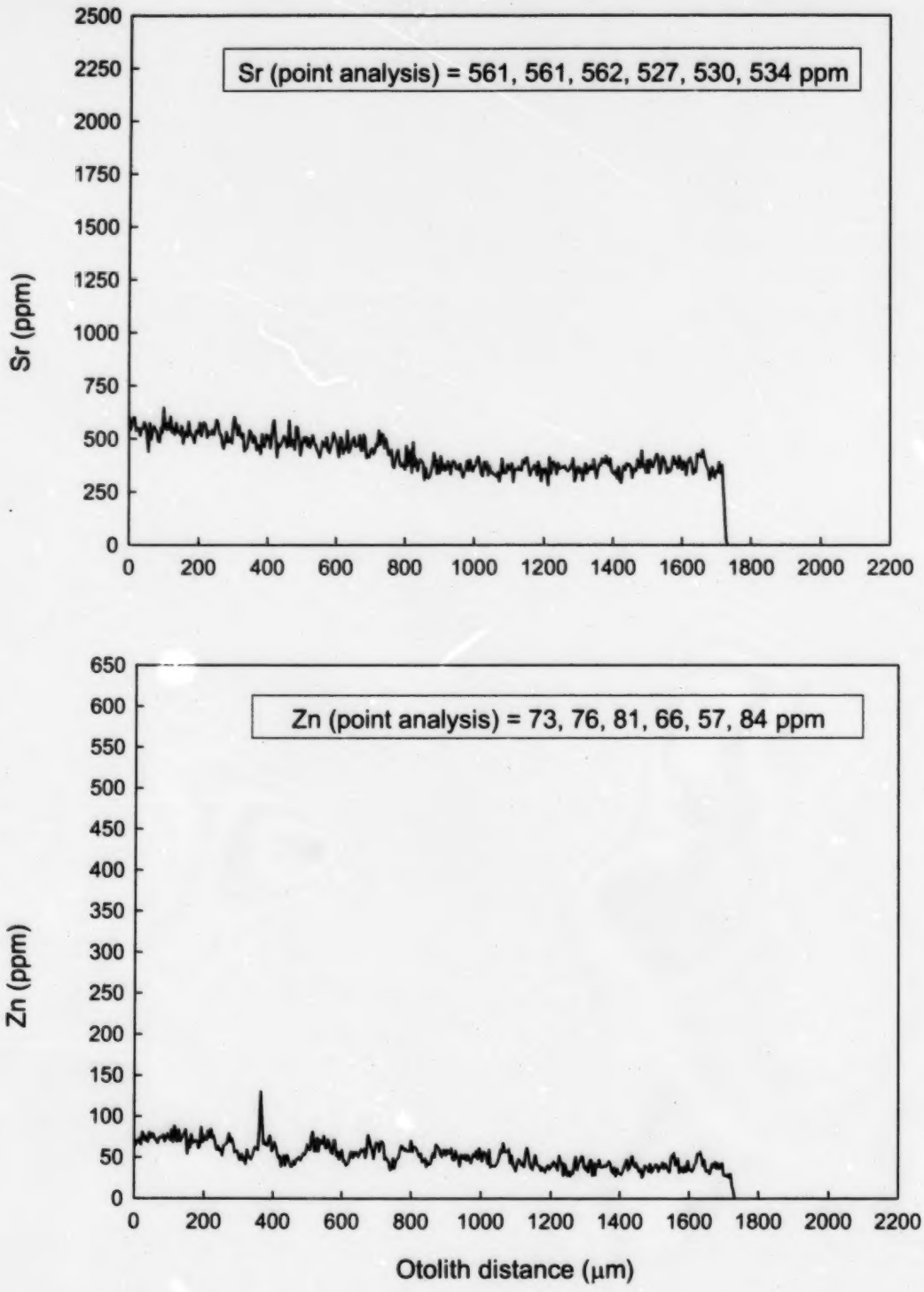

Fig. 83. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (452 mm, 836 g, male, 19 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

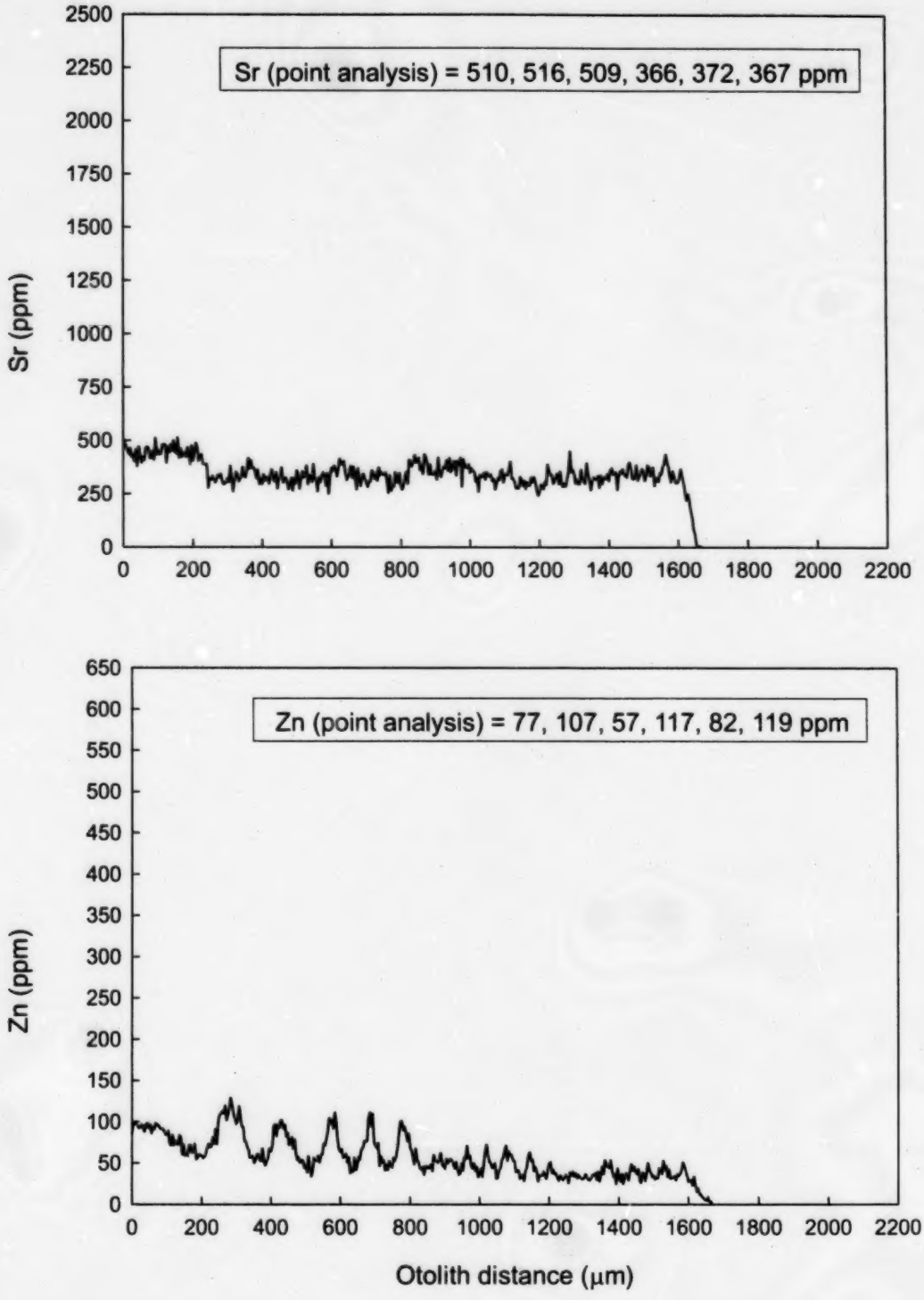

Fig. 84. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (569 mm, 2037 g, male, 21 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

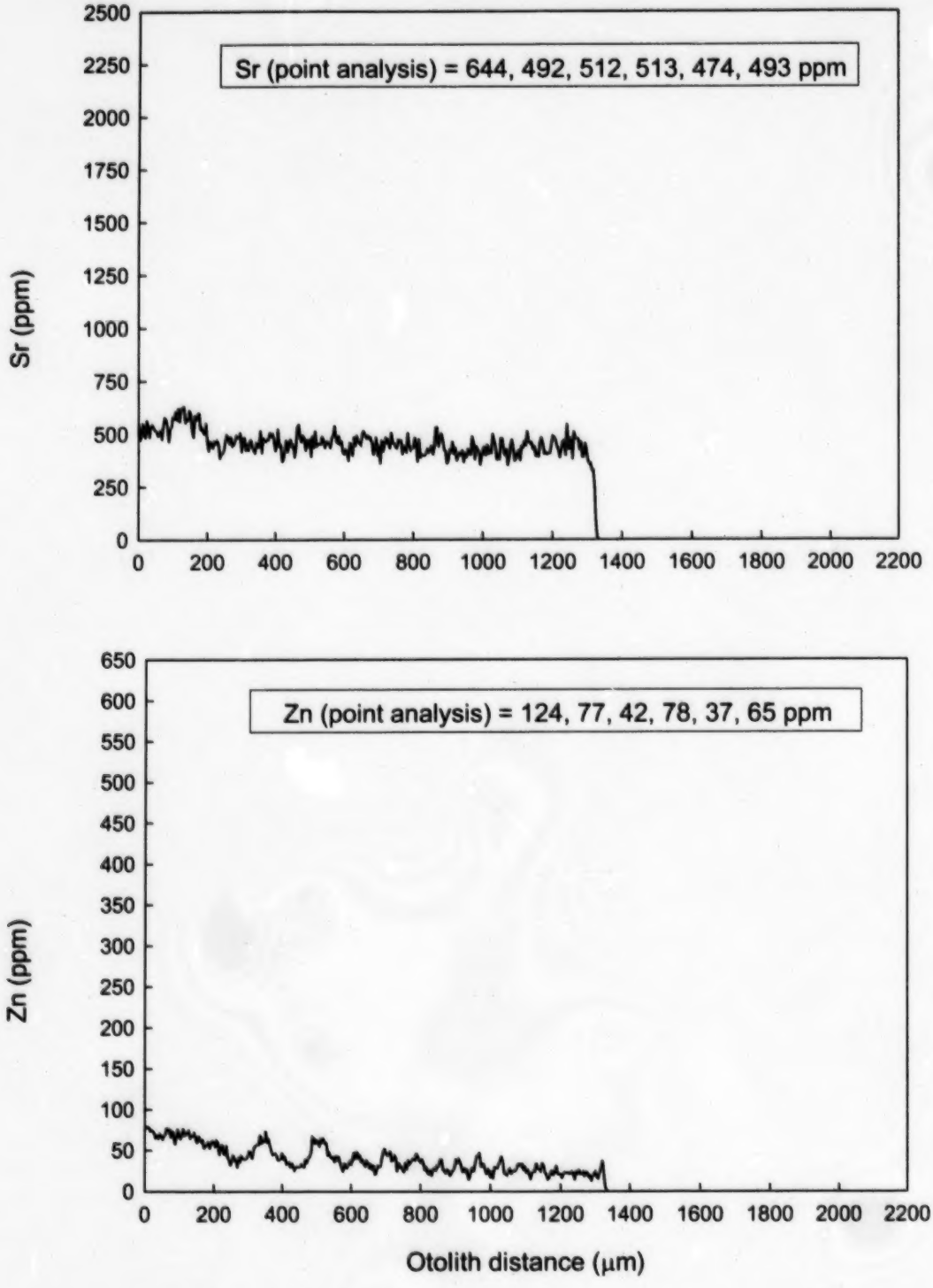

Fig. 85. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (301 mm, 236 g, female, 16 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

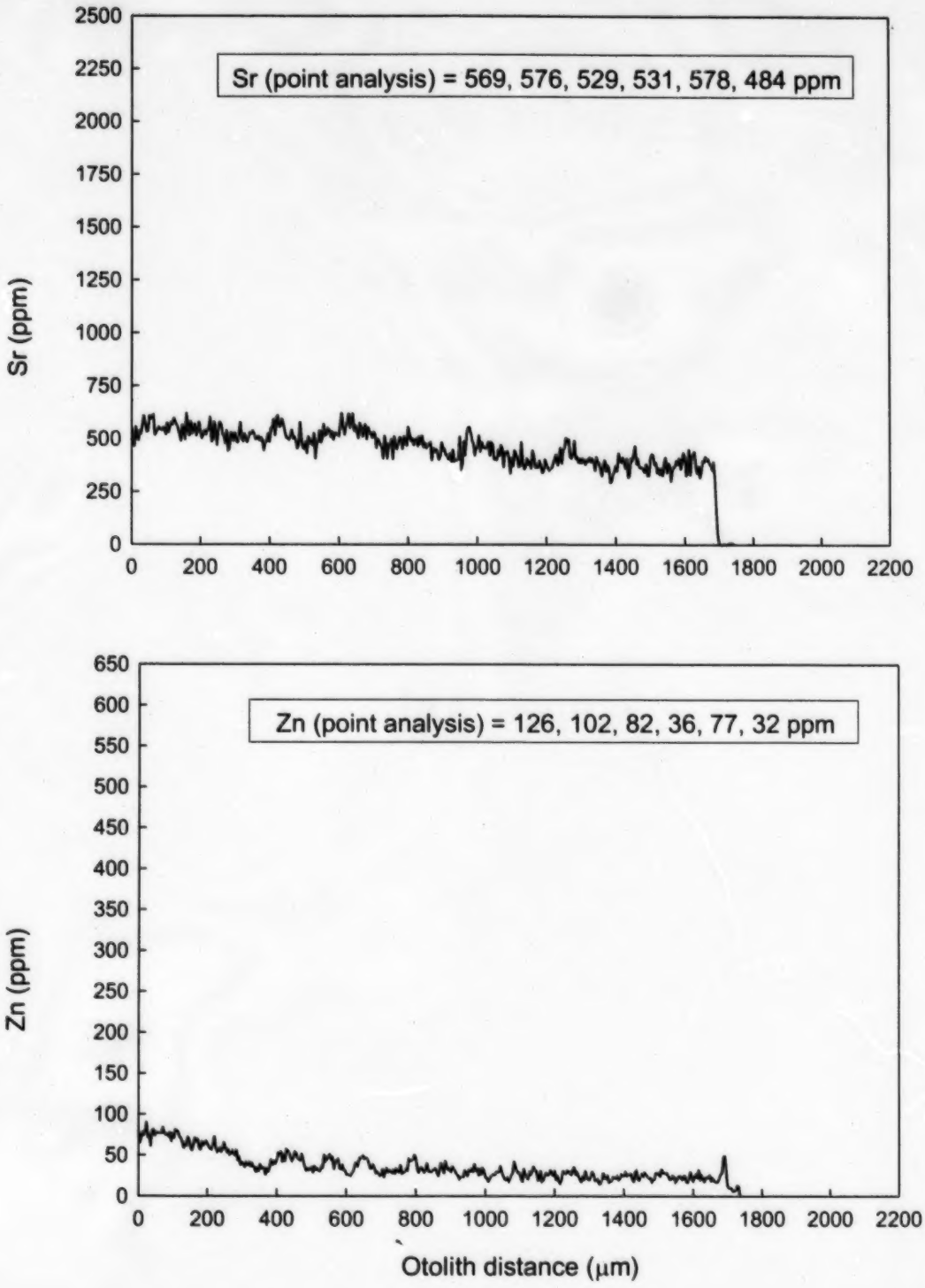

Fig. 86. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (565 mm, 1645 g, male, 21 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

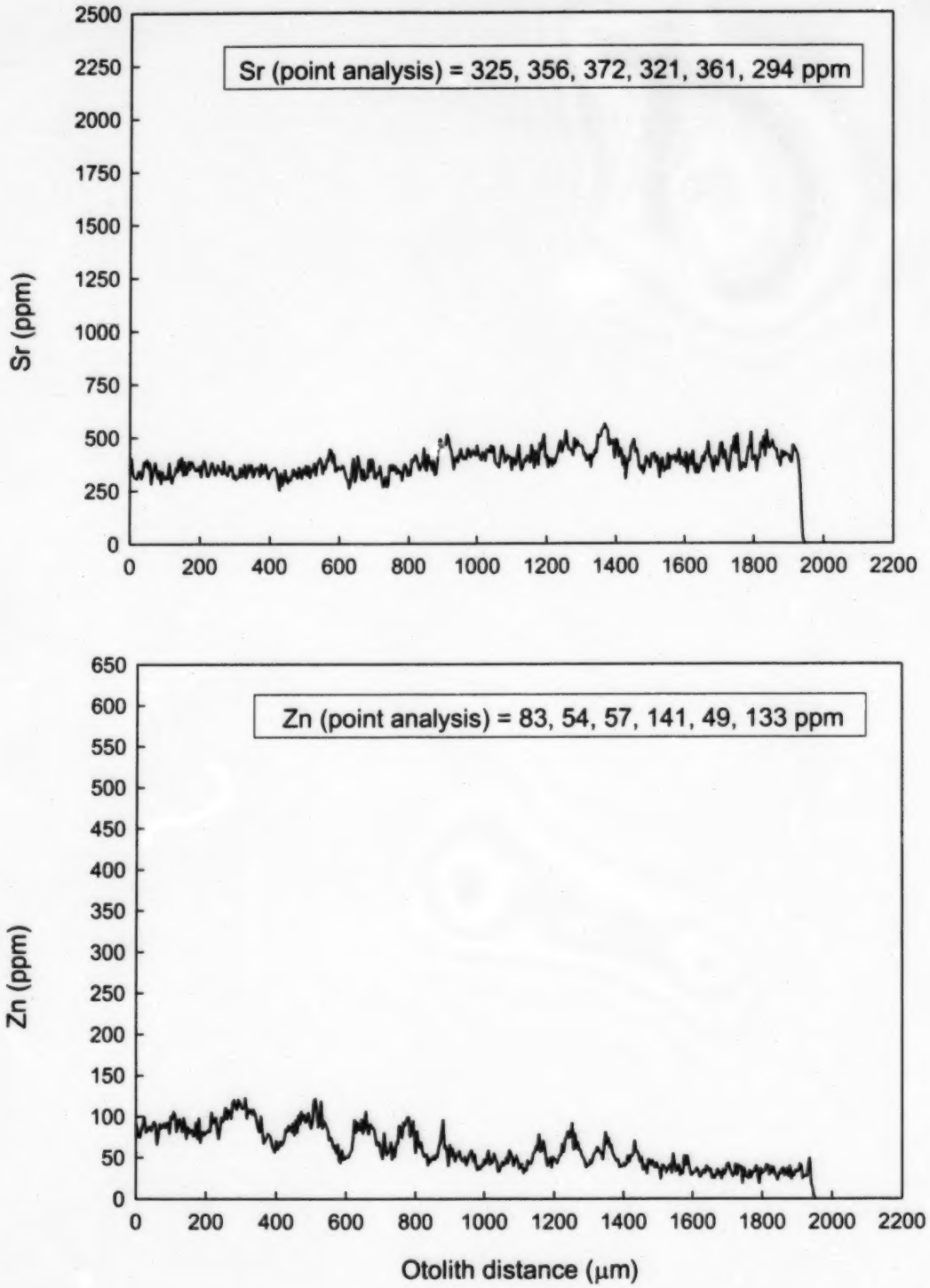

Fig. 87. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (672 mm, 1836 g, male, 25 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

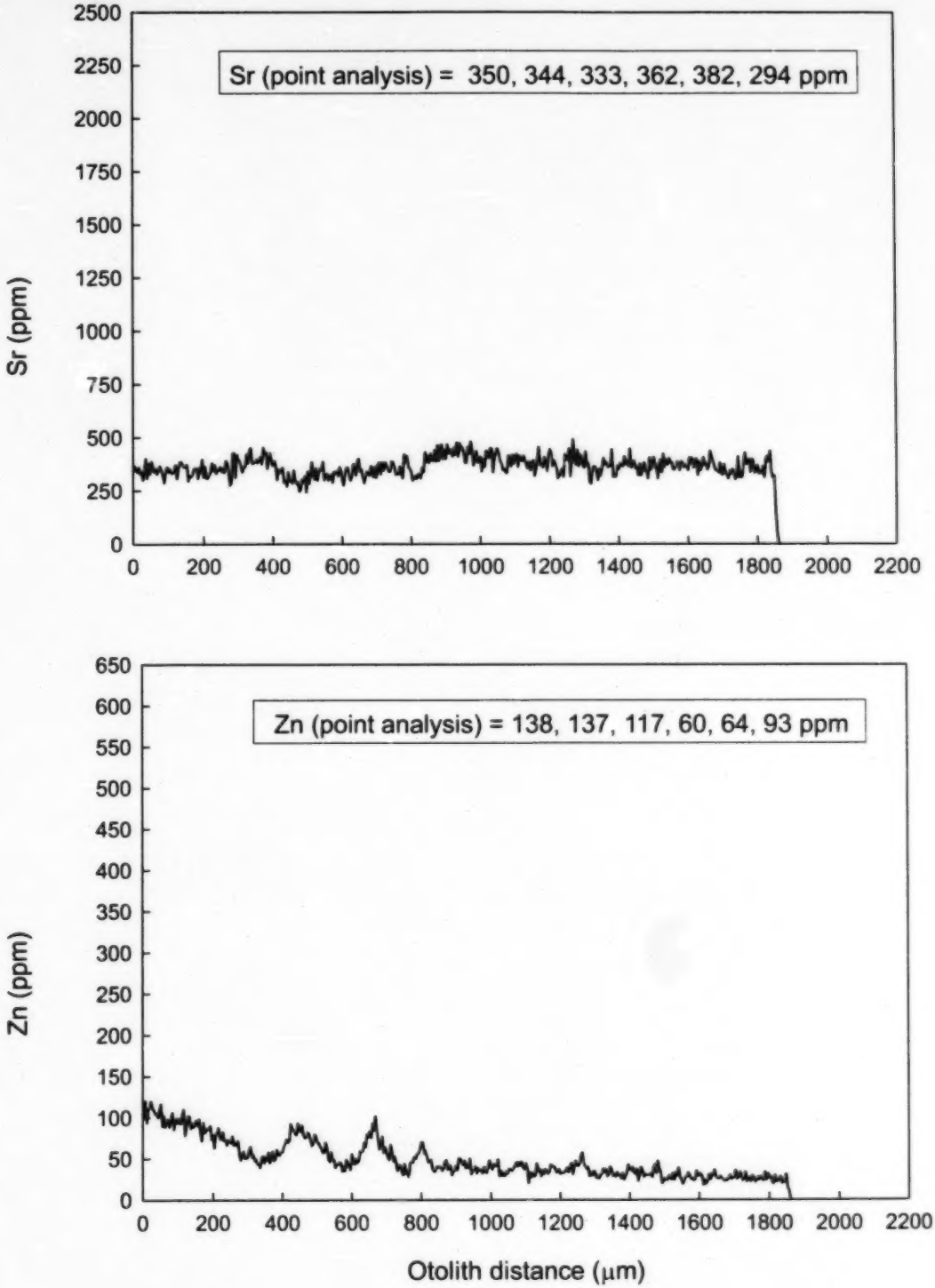

Fig. 88. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (518 mm, 1275 g, female, 19 yr) caught in Lake Hazen, June 1992. Point analysis results are also indicated.

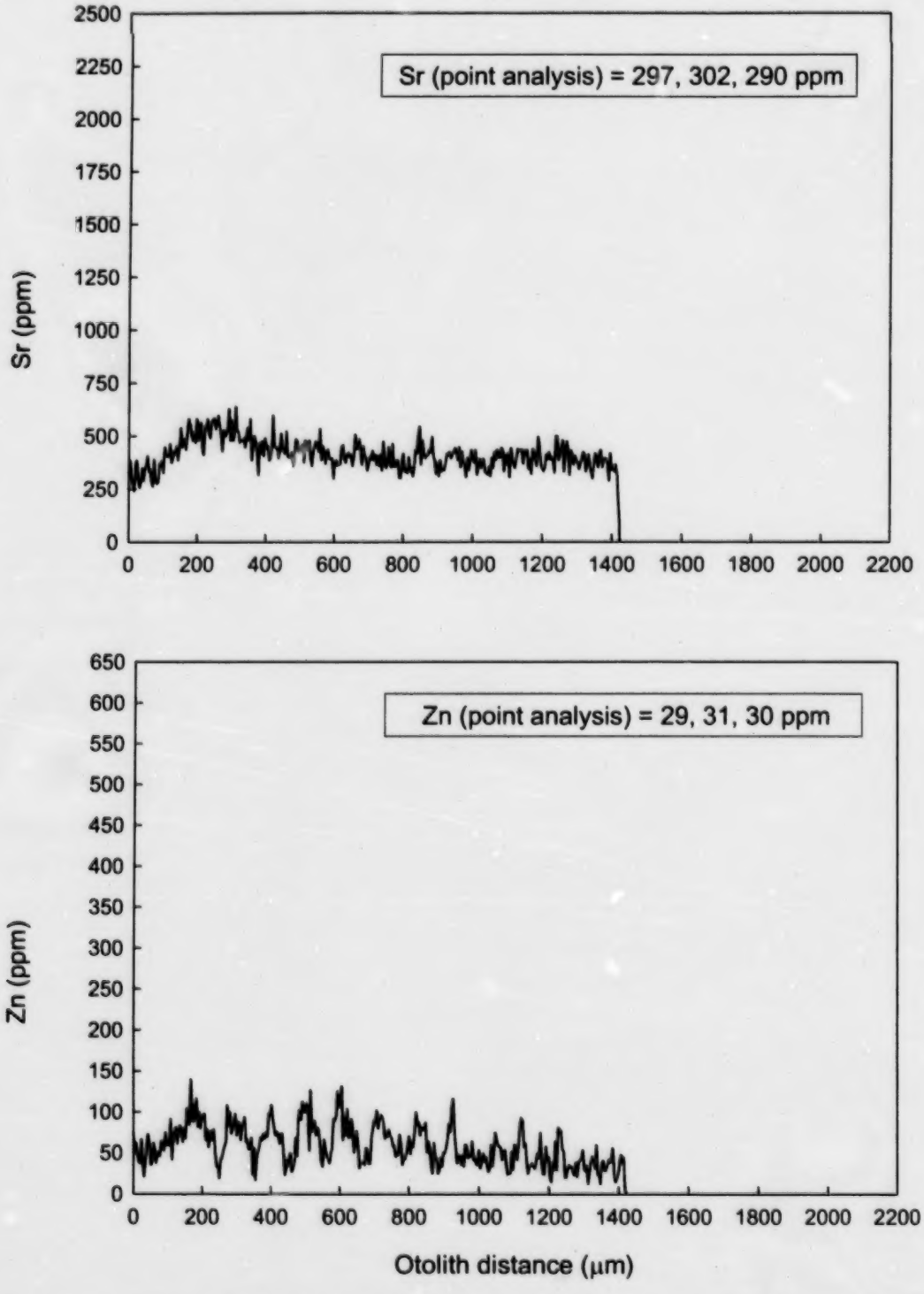

Fig. 89. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (435 mm, 810 g, female, 16 yr) caught in Lake Hazen, August 1998. Point analysis results are also indicated.

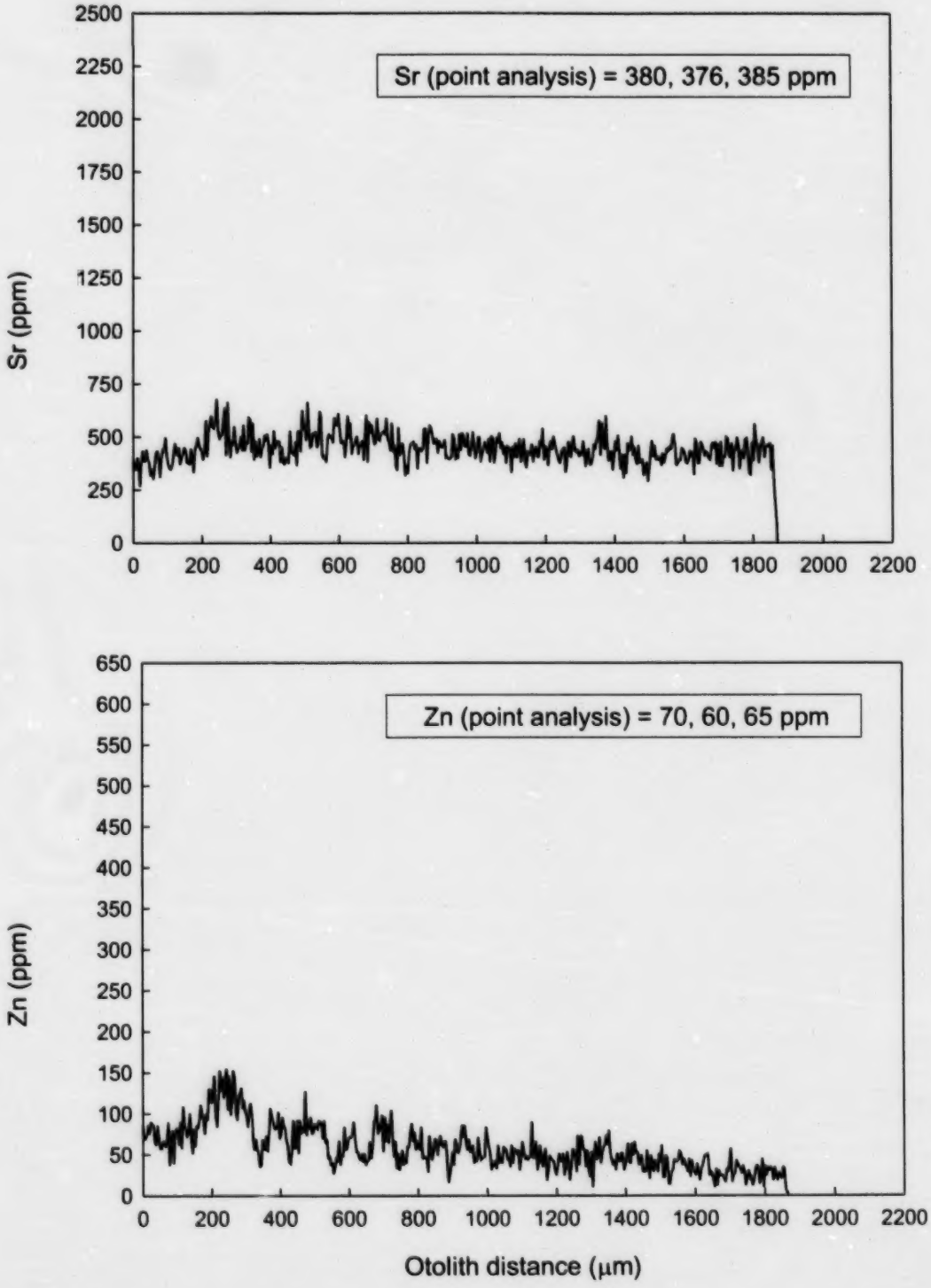

Fig. 90. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (533 mm, 1270 g, female, 25 yr) caught in Lake Hazen, August 1998. Point analysis results are also indicated.

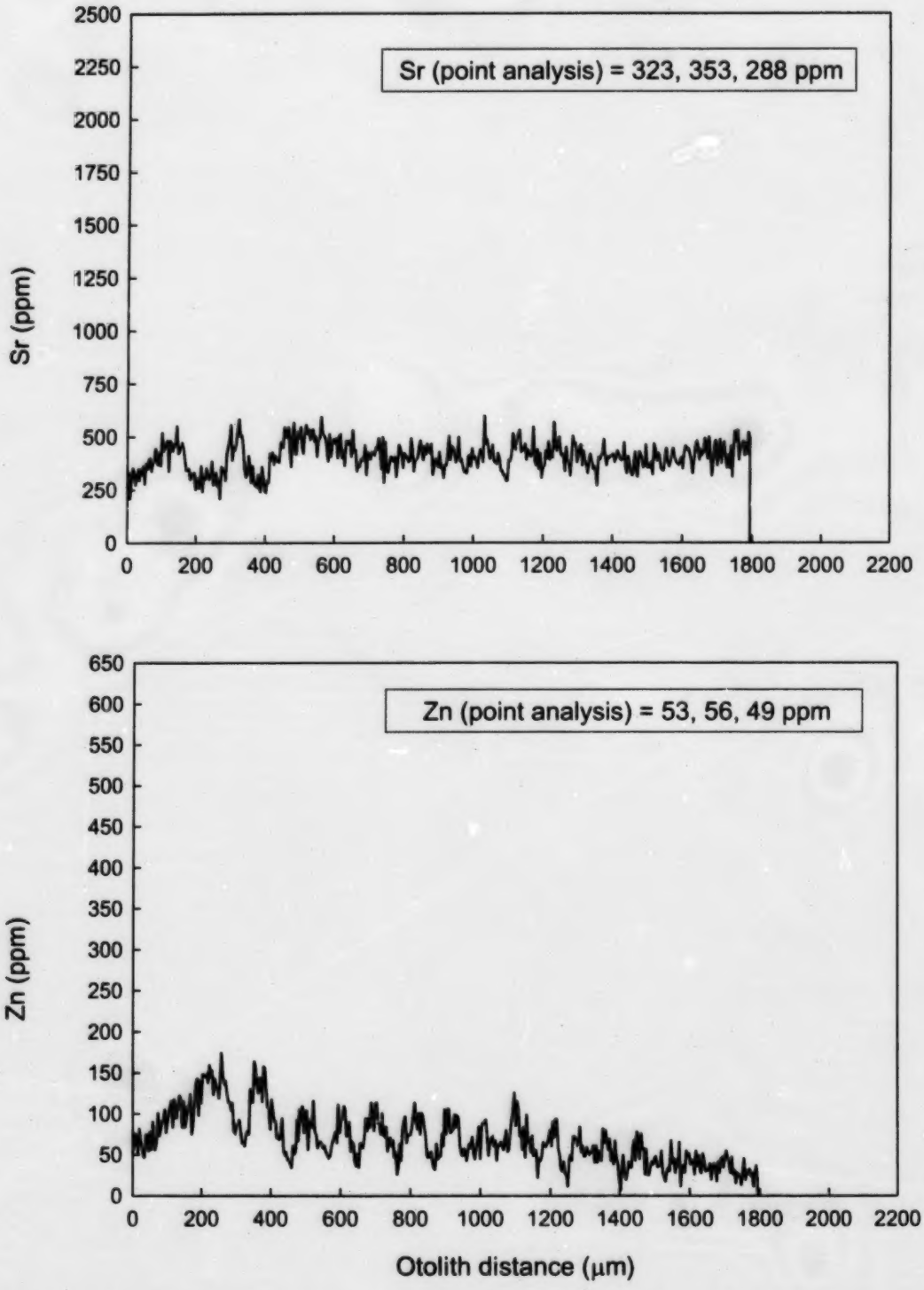

Fig. 91. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (630 mm, 1820 g, male, 21 yr) caught in Lake Hazen, August 1998. Point analysis results are also indicated.

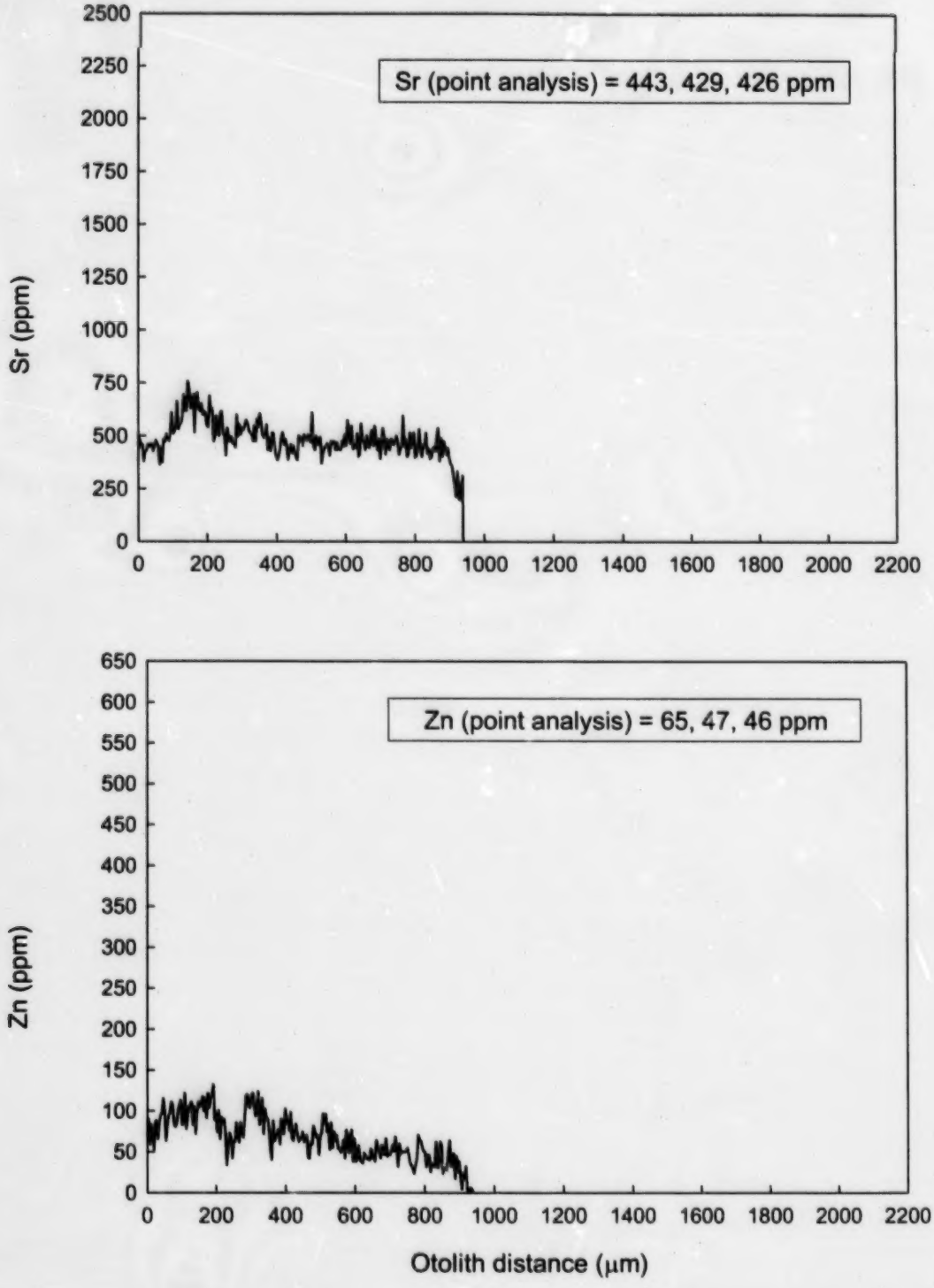

Fig. 92. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (177 mm, 48 g, male, 11 yr) of unknown form caught in Lake Hazen, July 1998. Point analysis results are also indicated.

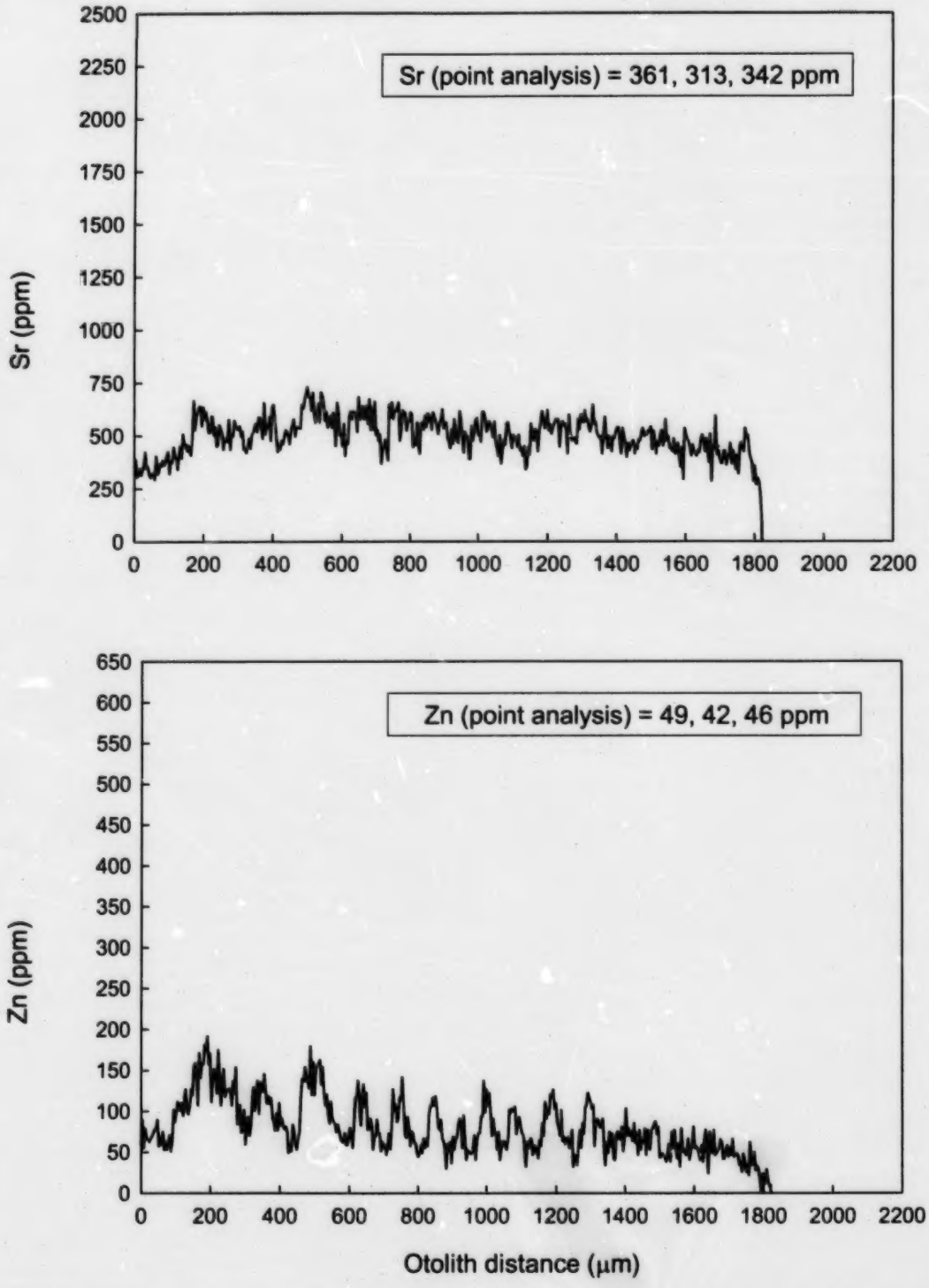

Fig. 93. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (644 mm, 2410 g, male, 21 yr) caught in Lake Hazen, August 1998. Point analysis results are also indicated.

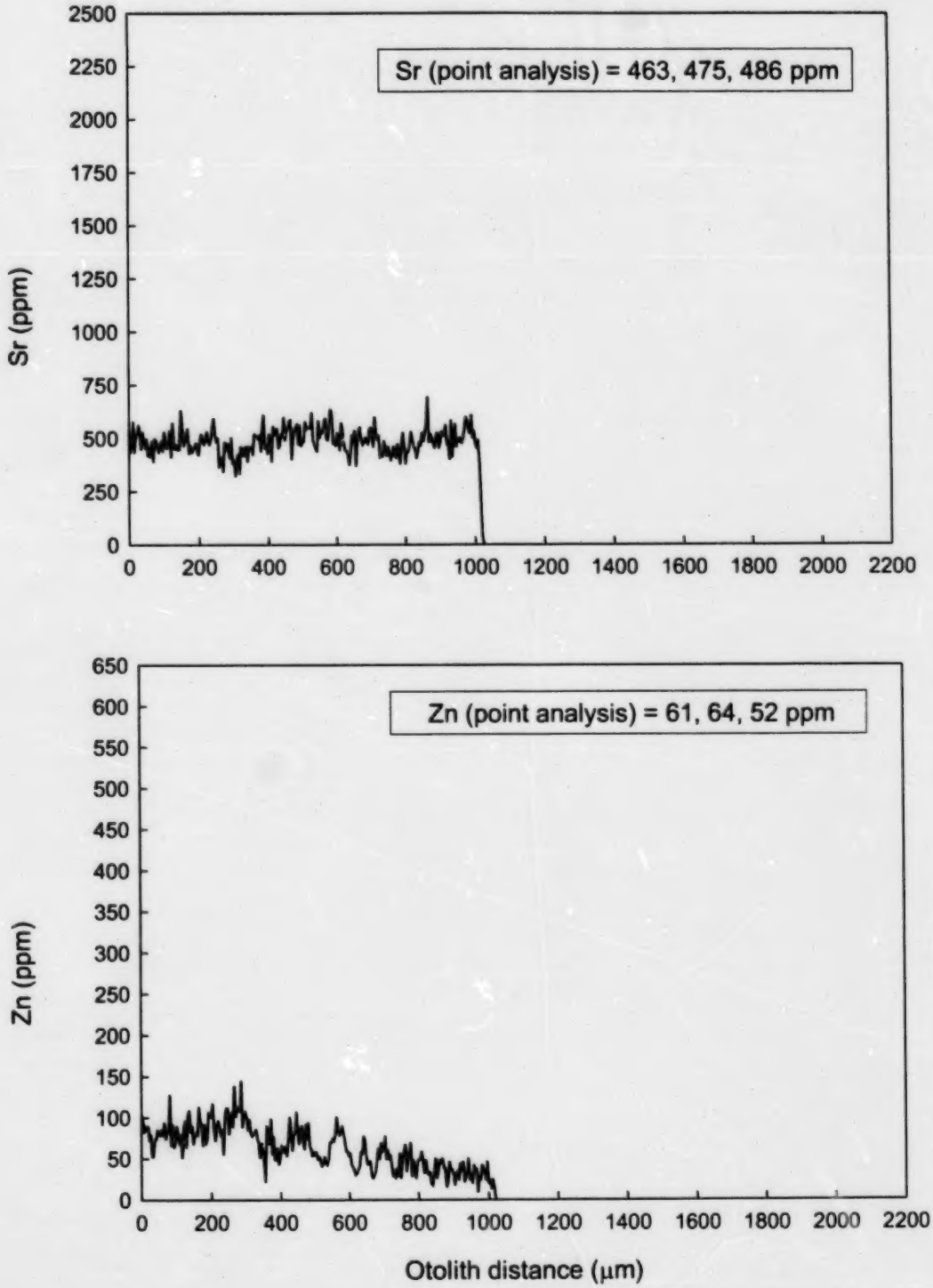

Fig. 94. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (172 mm, 42 g, female, 13 yr) of unknown form caught in Lake Hazen, July 1998. Point analysis results are also indicated.

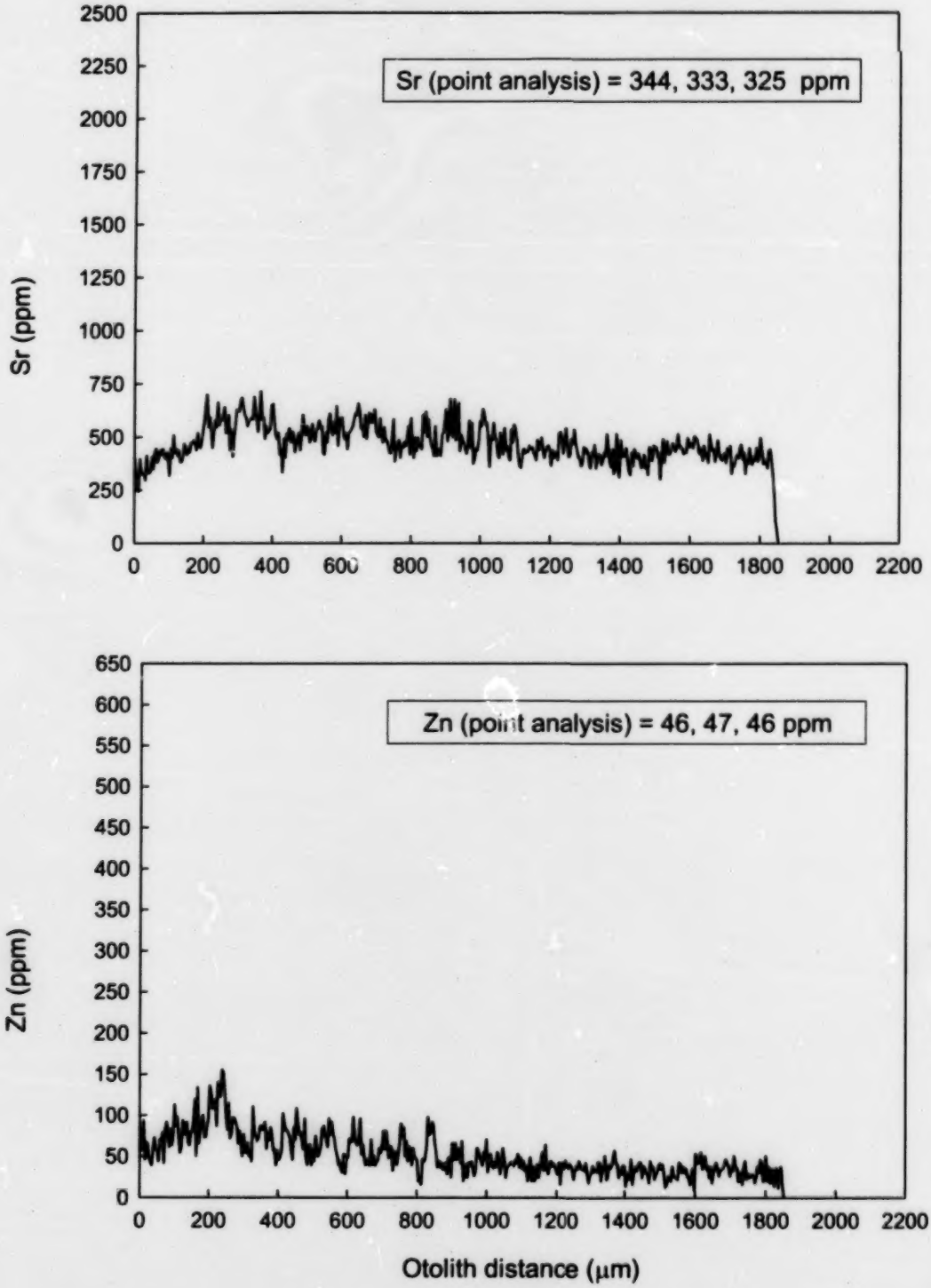

Fig. 95. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (524 mm, 1190 g, female, 22 yr) caught in Lake Hazen, August 1998. Point analysis results are also indicated.

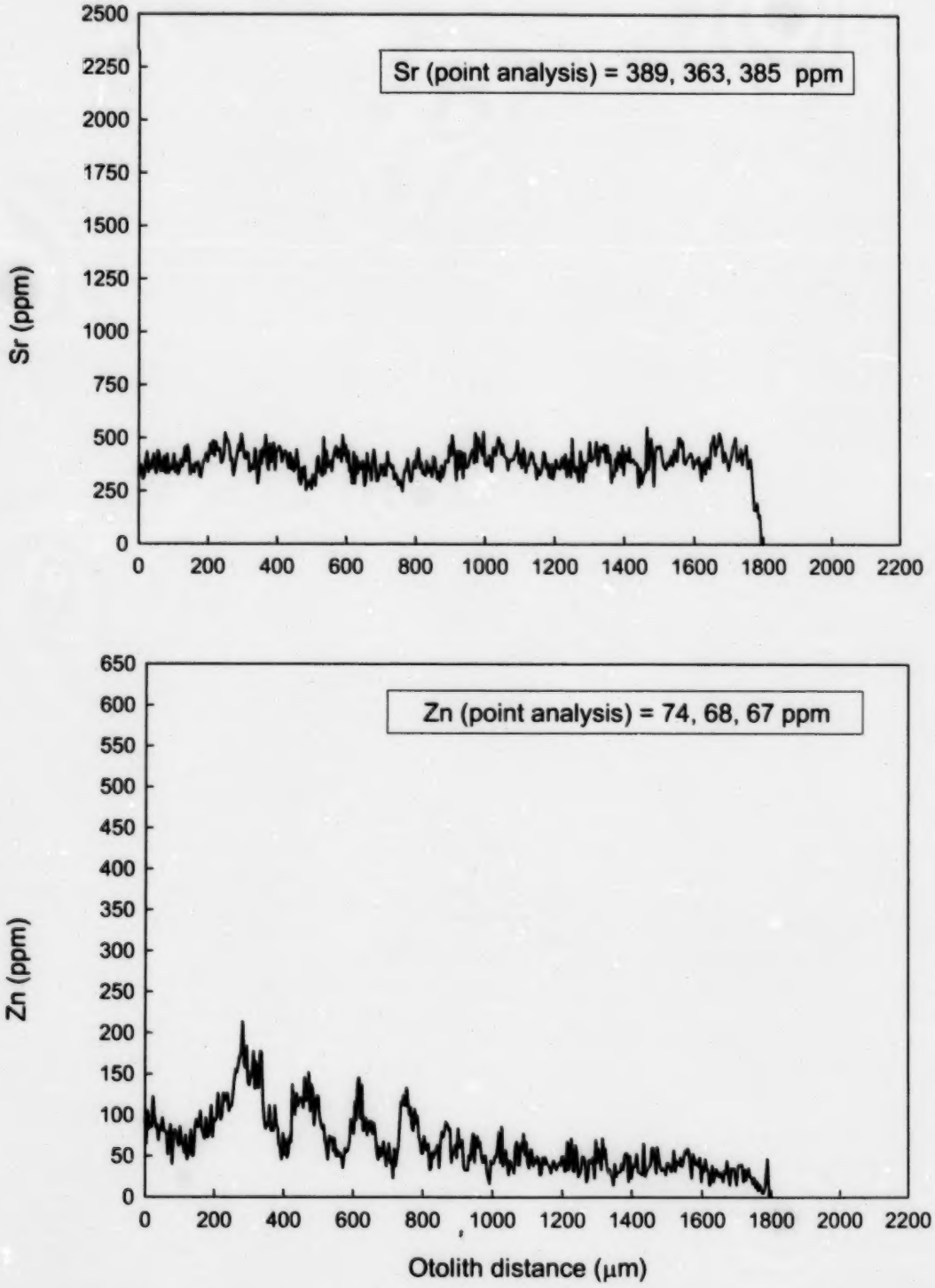

Fig. 96. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (549 mm, 1805 g, female, 20 yr) caught in Lake Hazen, July 1998. Point analysis results are also indicated.

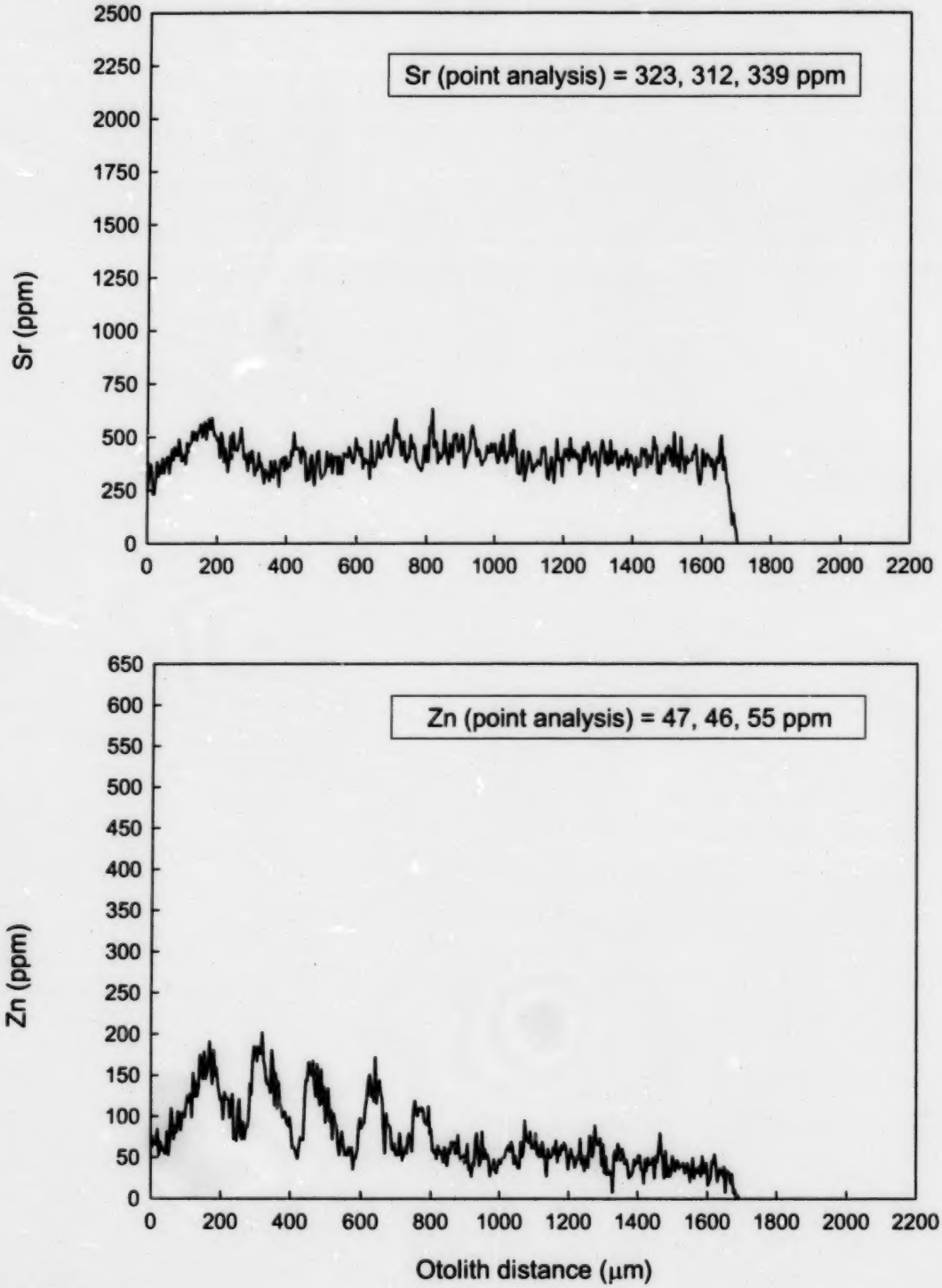

Fig. 97. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (531 mm, 1803 g, female, 18 yr) caught in Lake Hazen, July 1998. Point analysis results are also indicated.

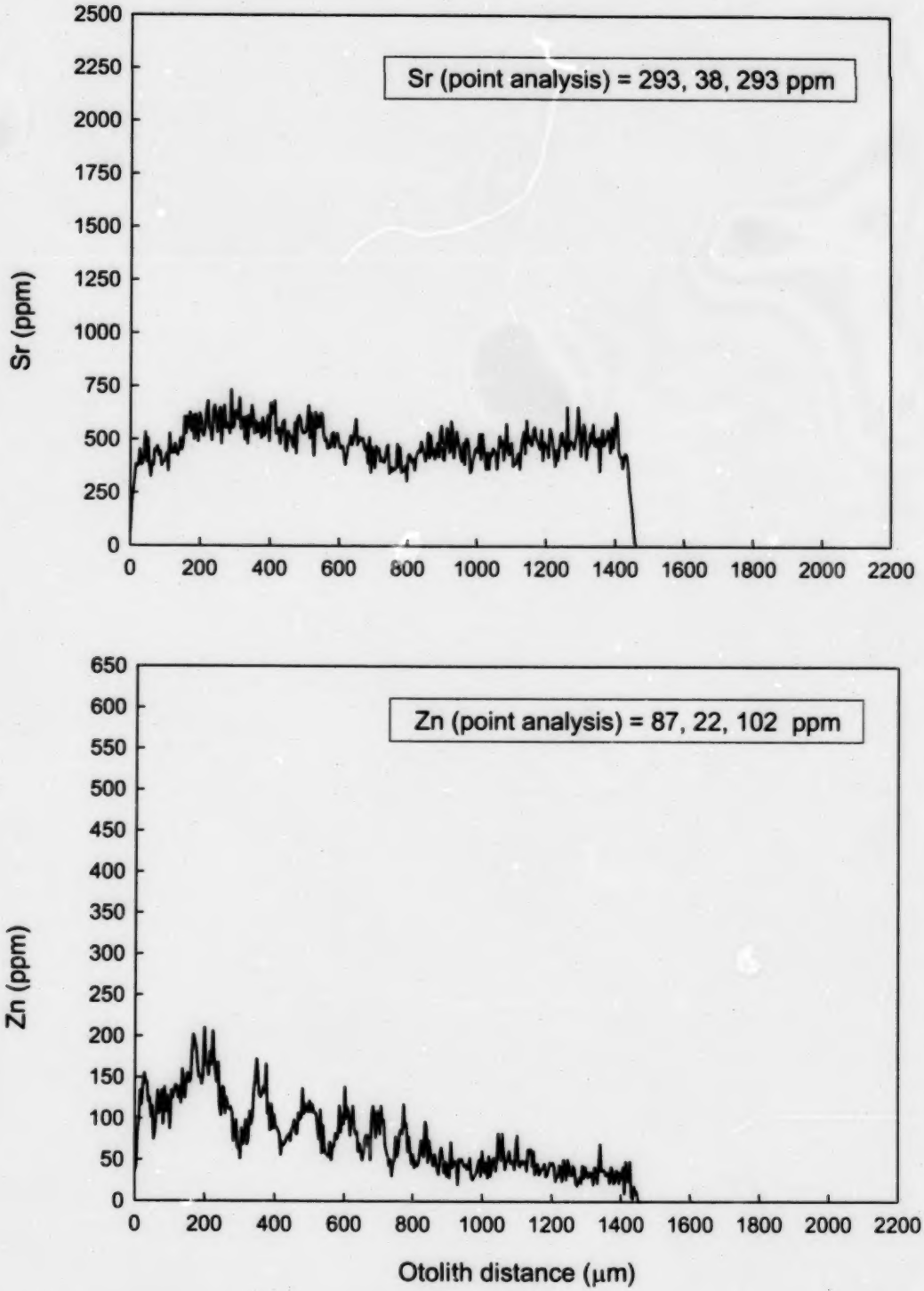

Fig. 98. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from a large-form Arctic char (397 mm, 520 g, male, 21 yr) caught in Lake Hazen, July 1998. Point analysis results are also indicated.

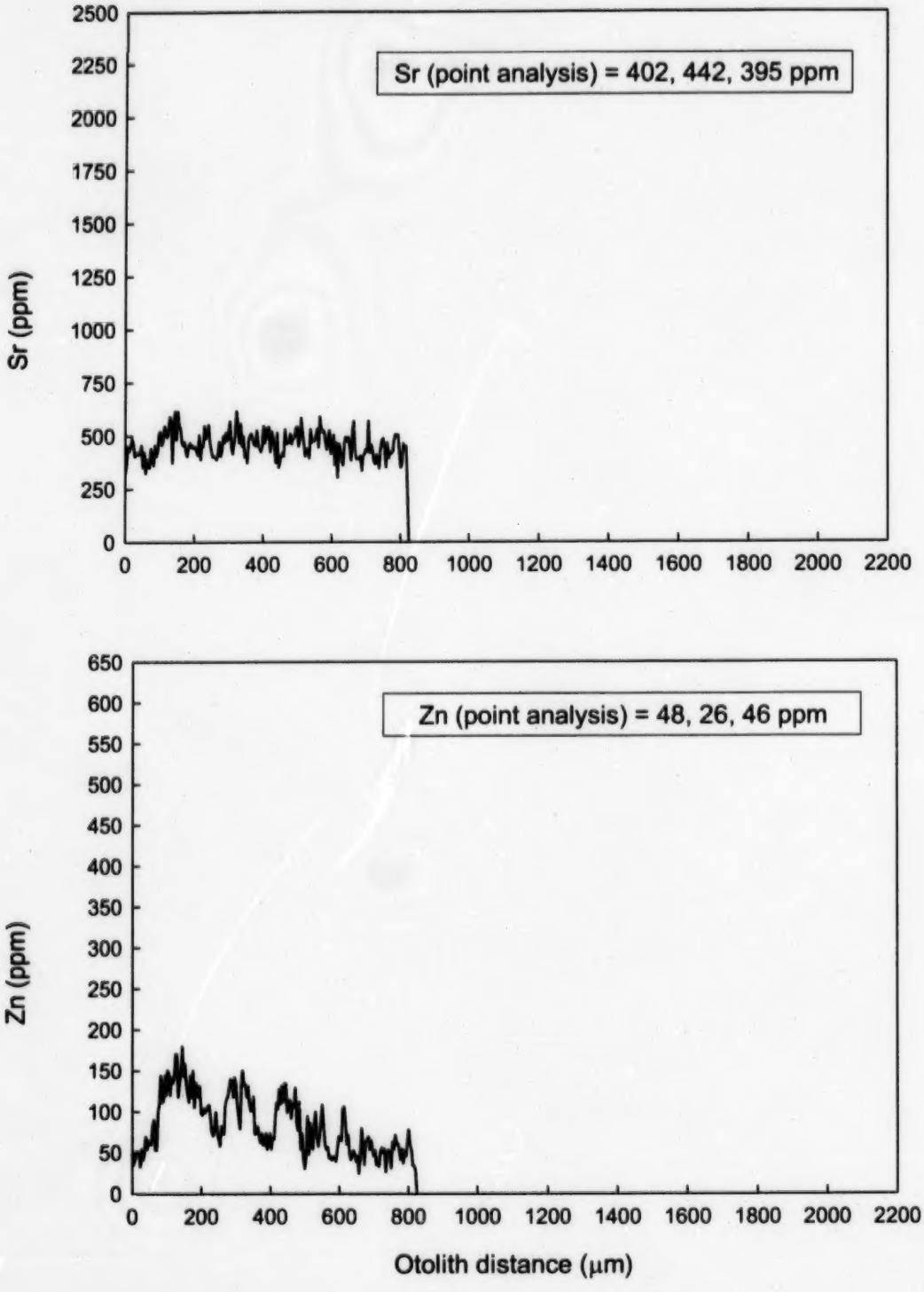

Fig. 99. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (174 mm, 126 g, female, 9 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

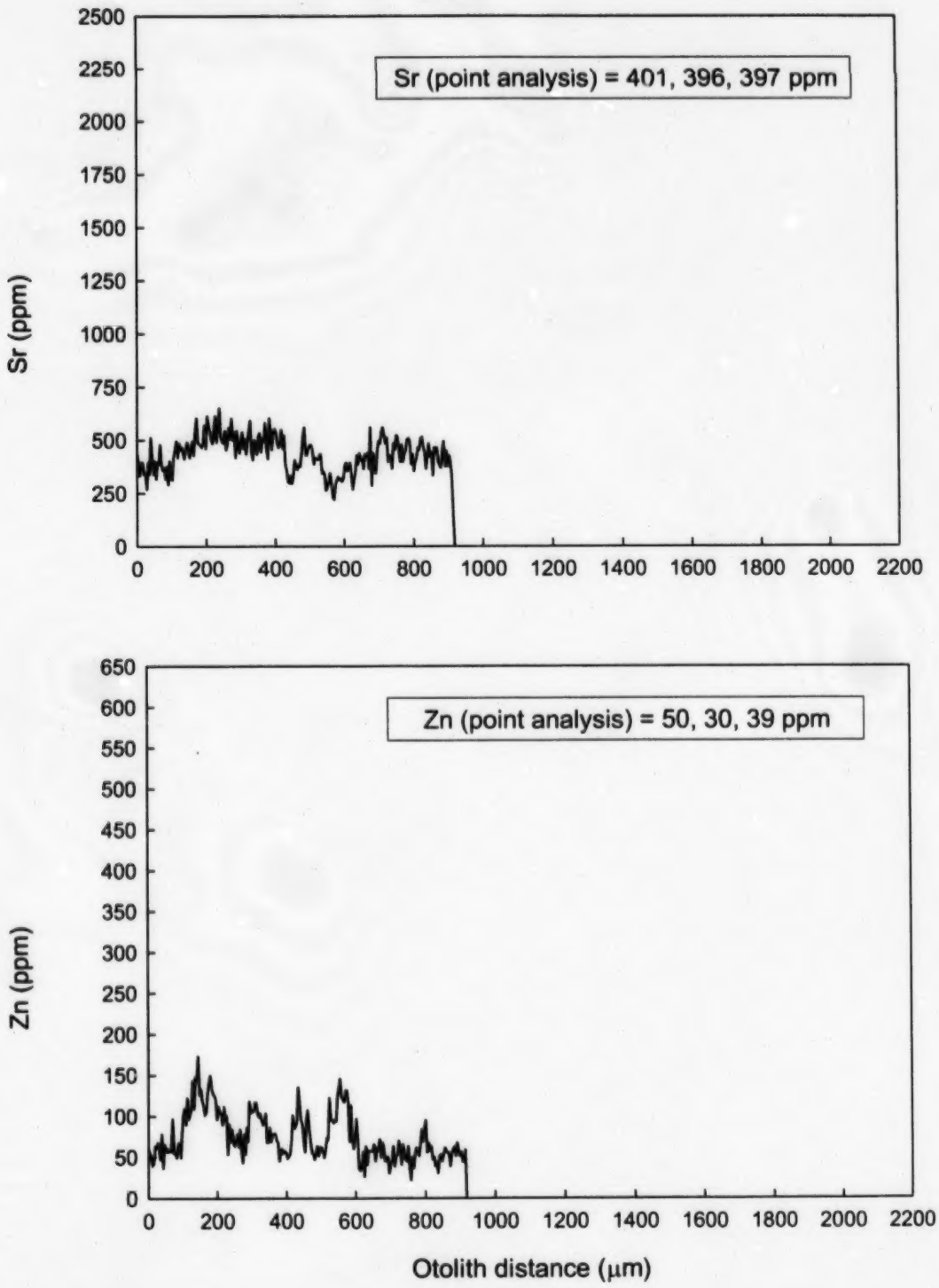

Fig. 100. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (243 mm, 261 g, male, 8 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

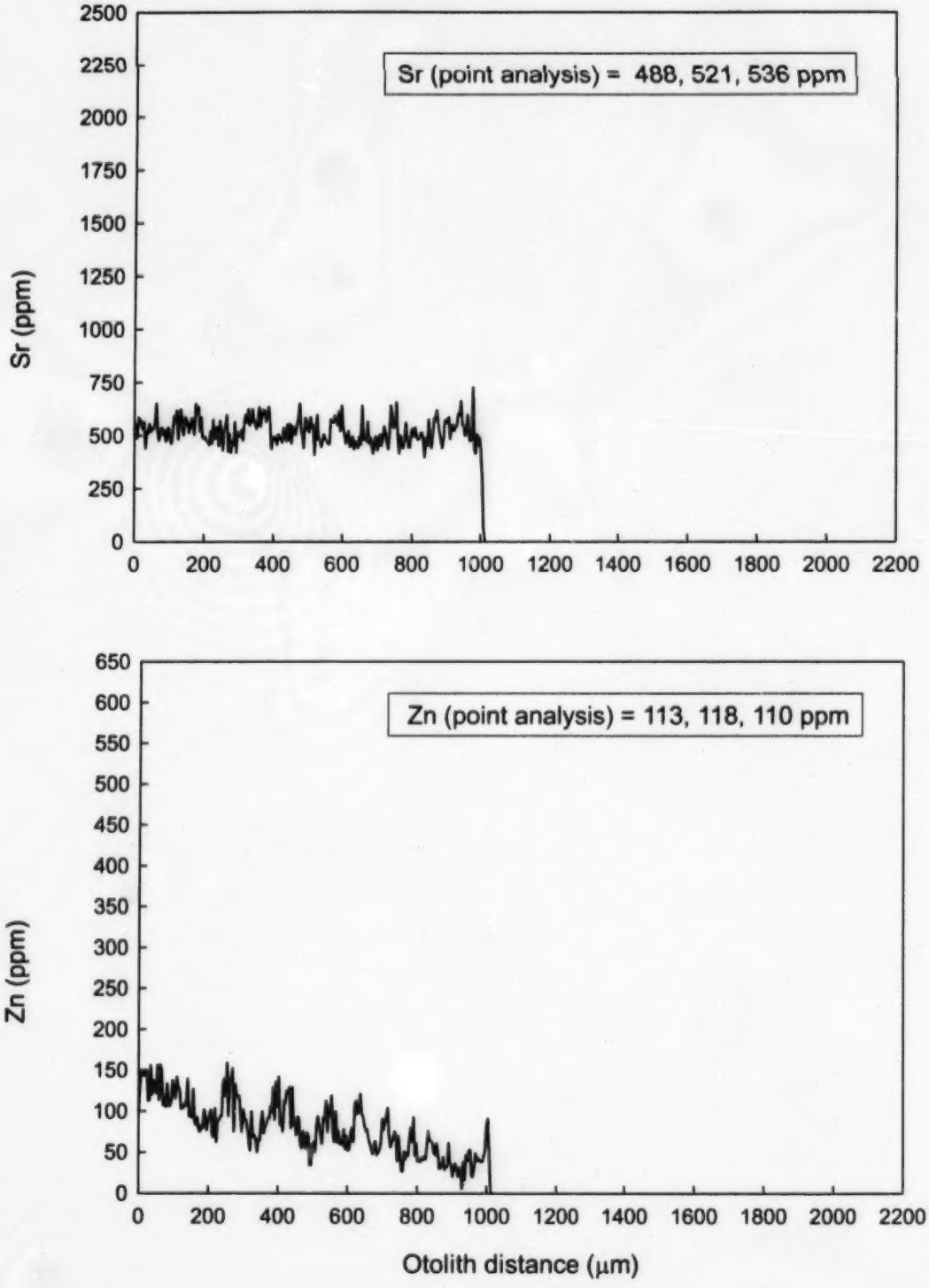

Fig. 101. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (231 mm, 227 g, female, 17 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

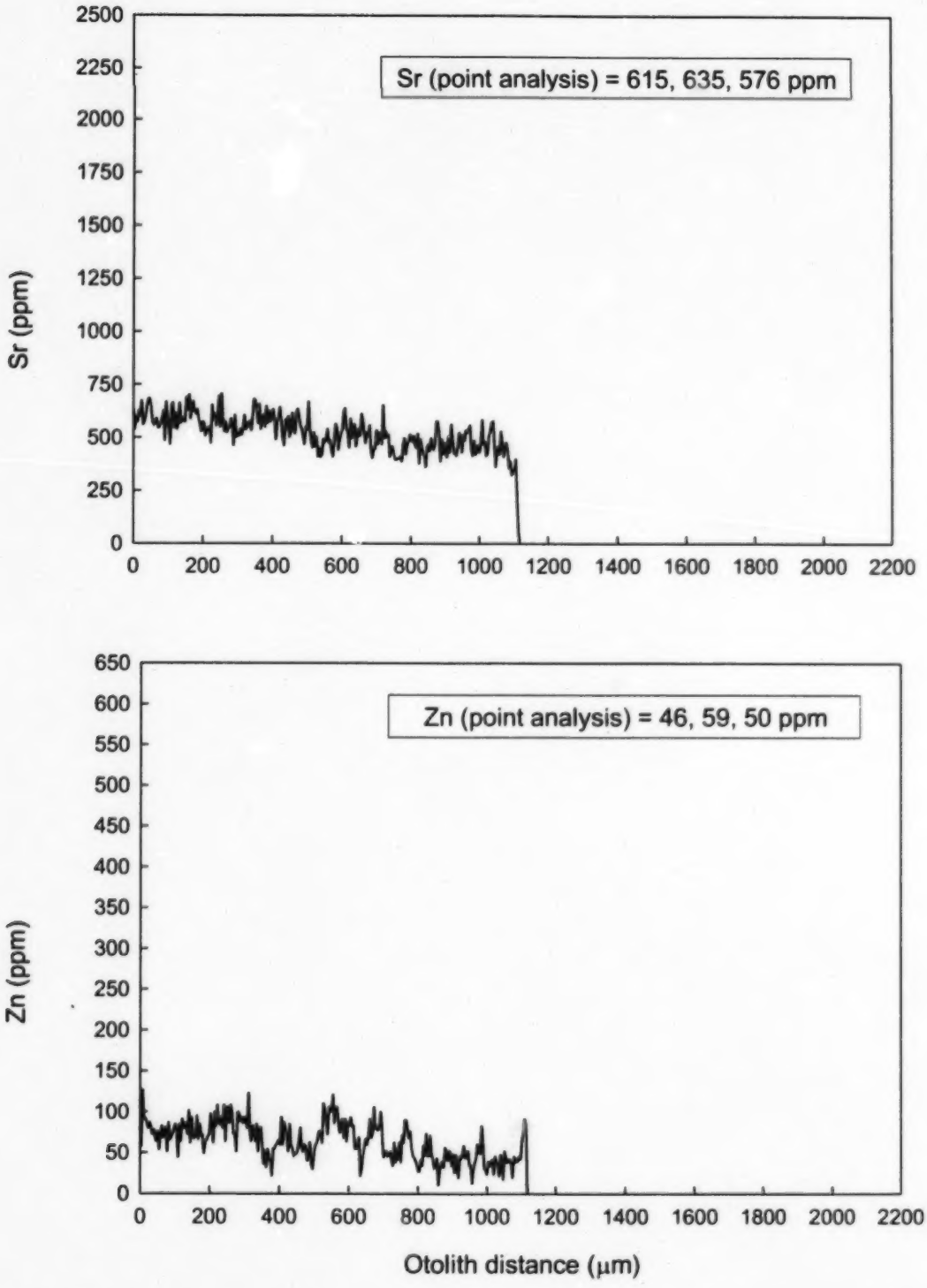

Fig. 102. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (187 mm, 146 g, male, 12 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

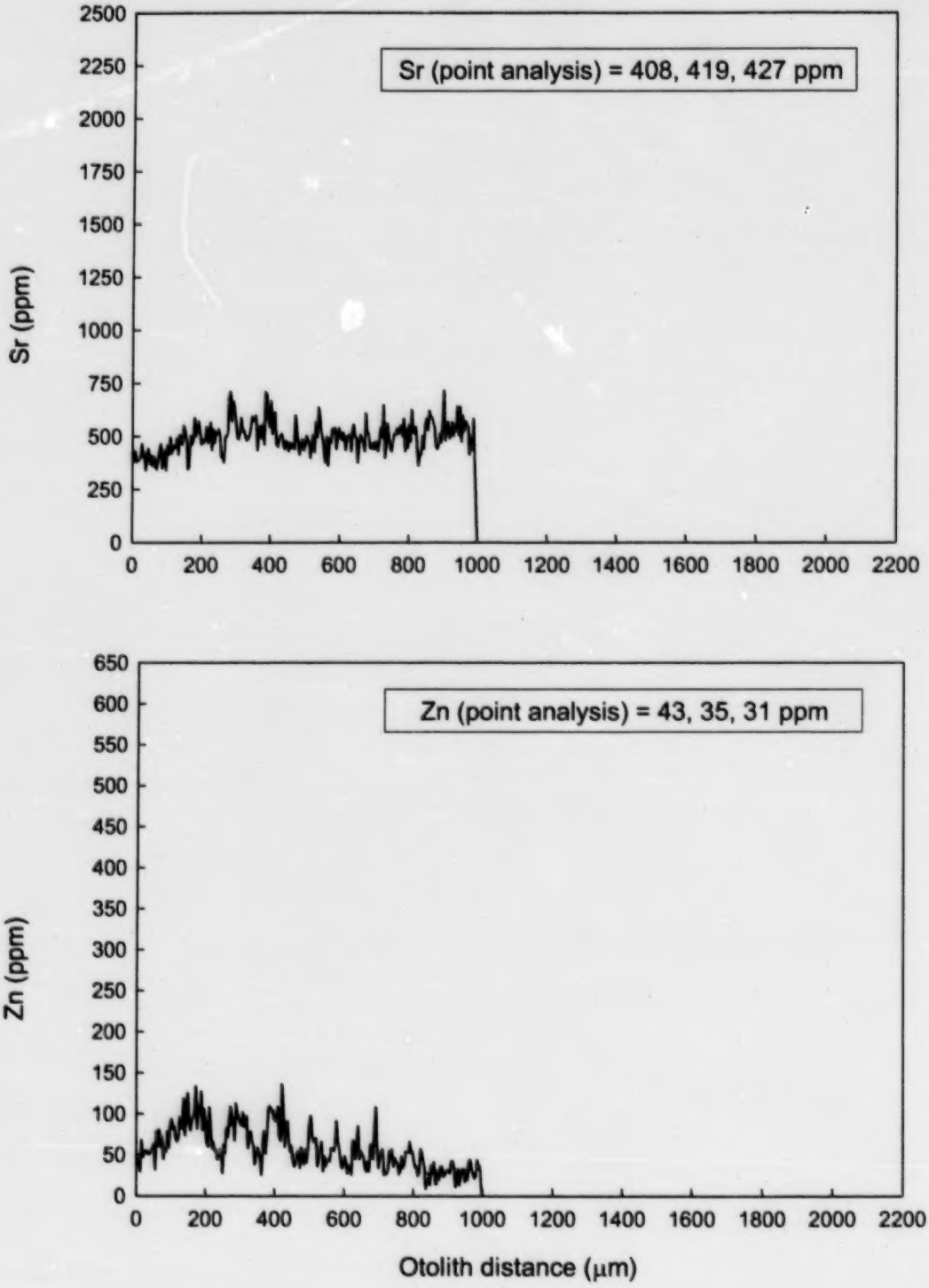

Fig. 103. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (198 mm, 164 g, female, 13 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

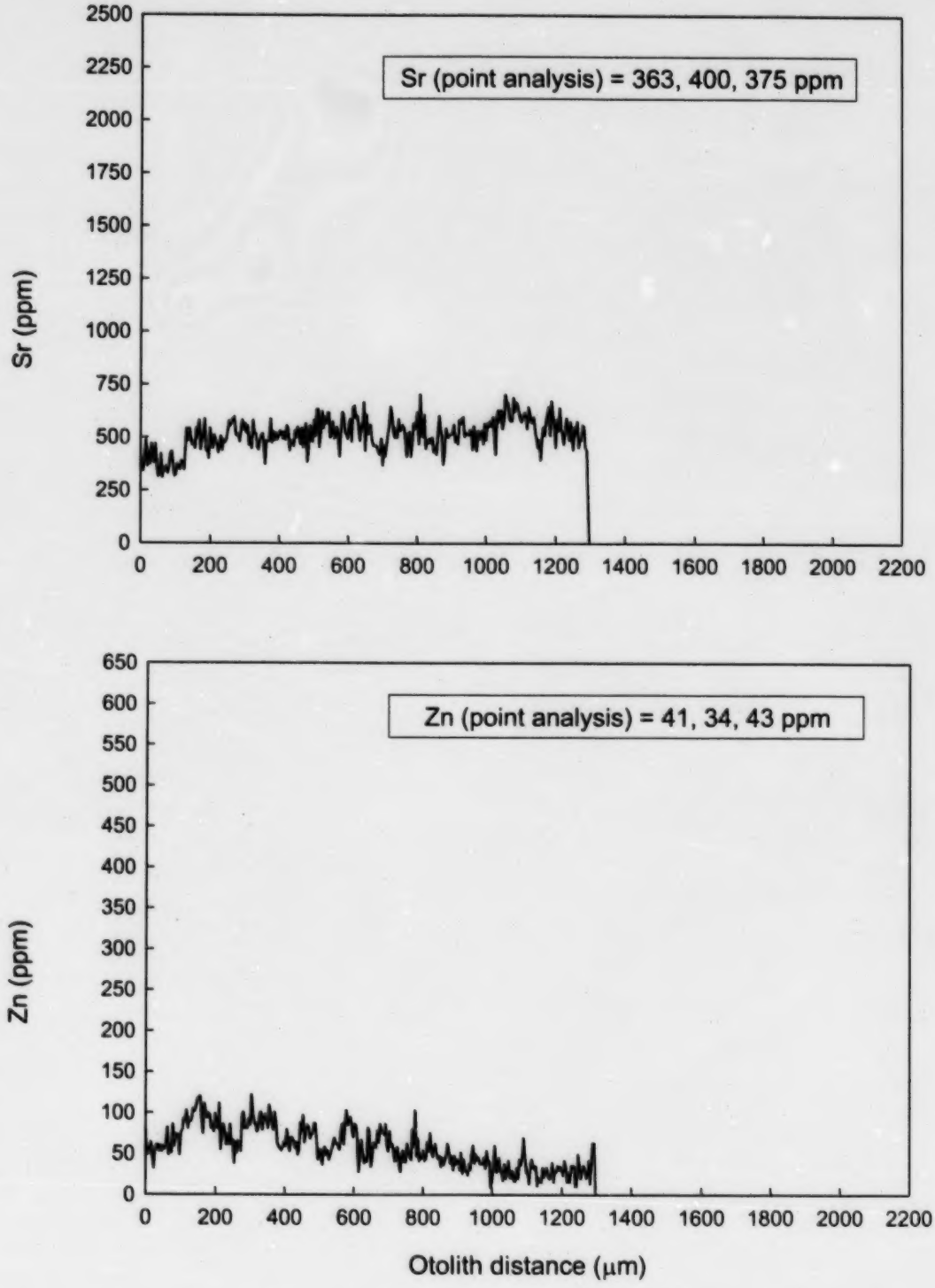

Fig. 104. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (224 mm, 209 g, male, 24 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

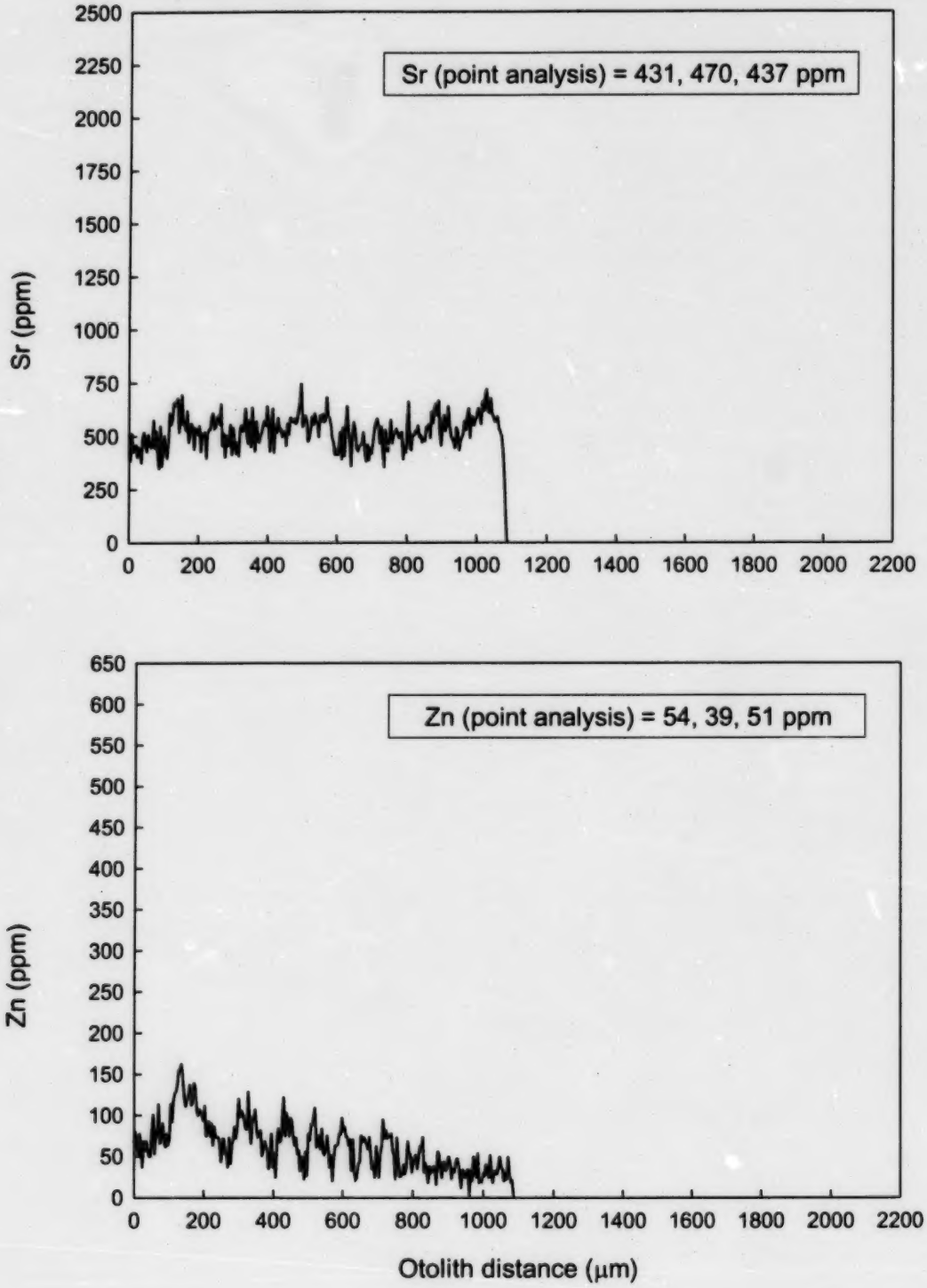

Fig. 105. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (246 mm, 292 g, female, 20 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

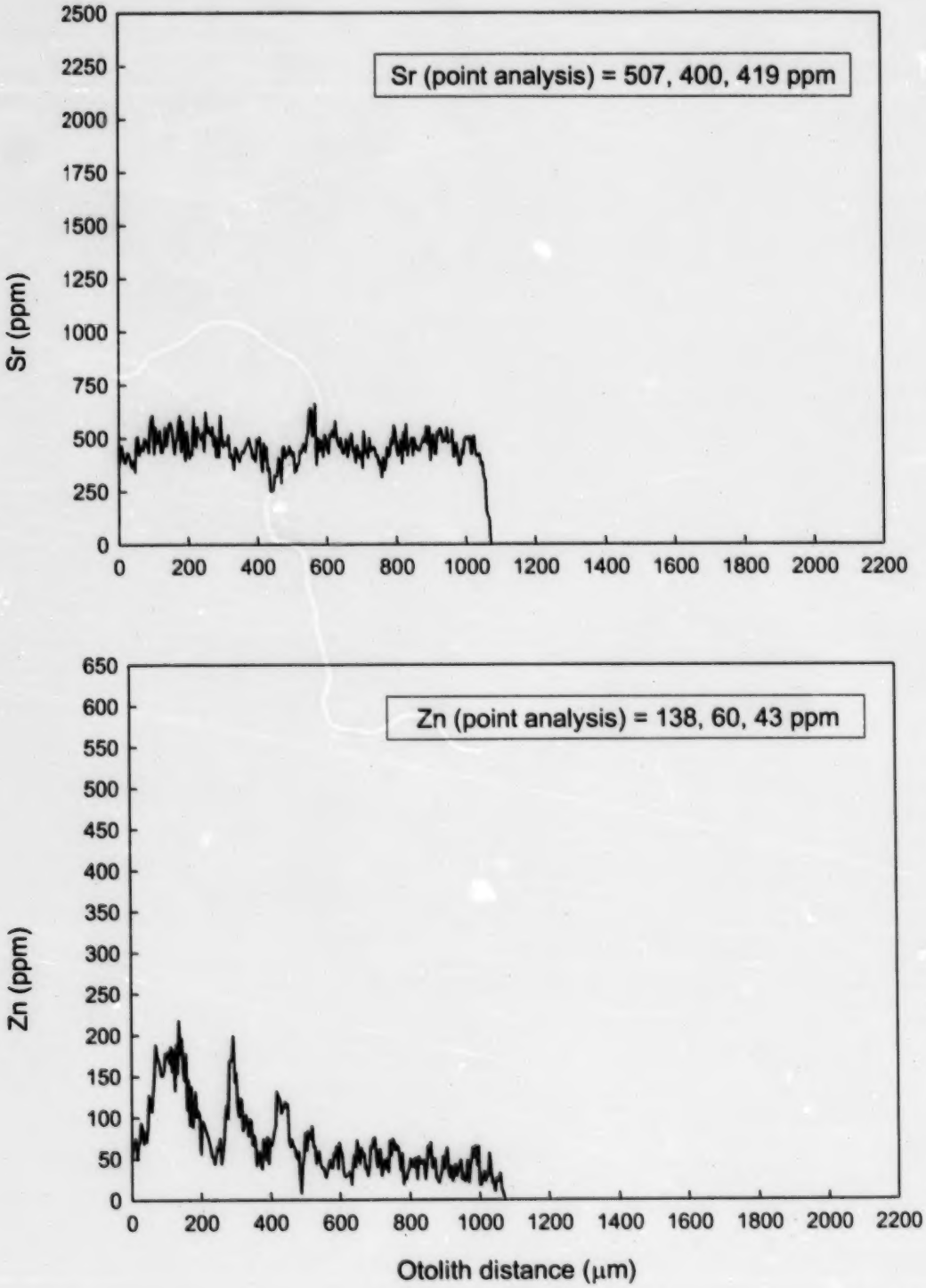

Fig. 106. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (252 mm, 314 g, male, 11 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

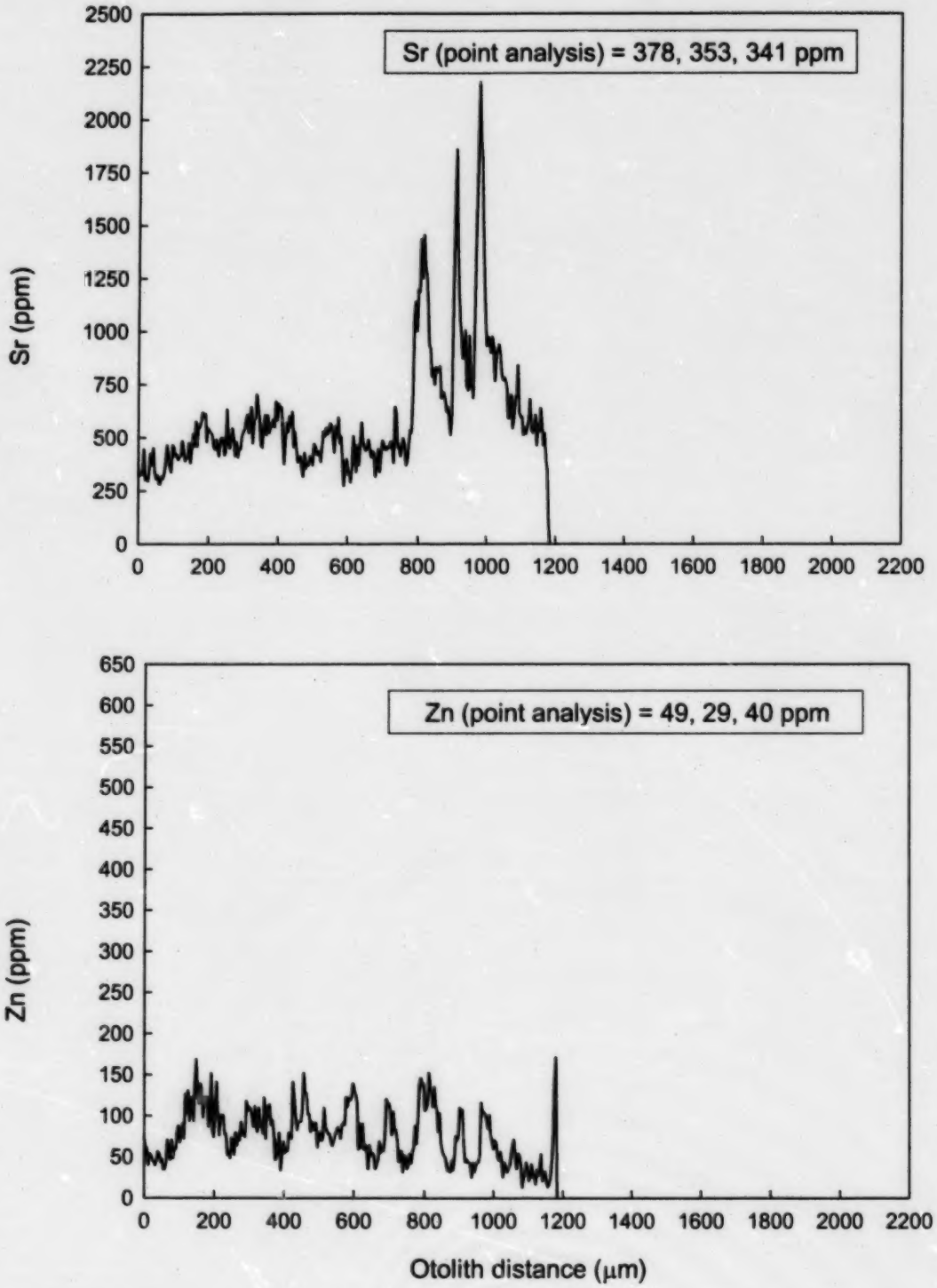

Fig. 107. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (285 mm, 511 g, female, 14 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

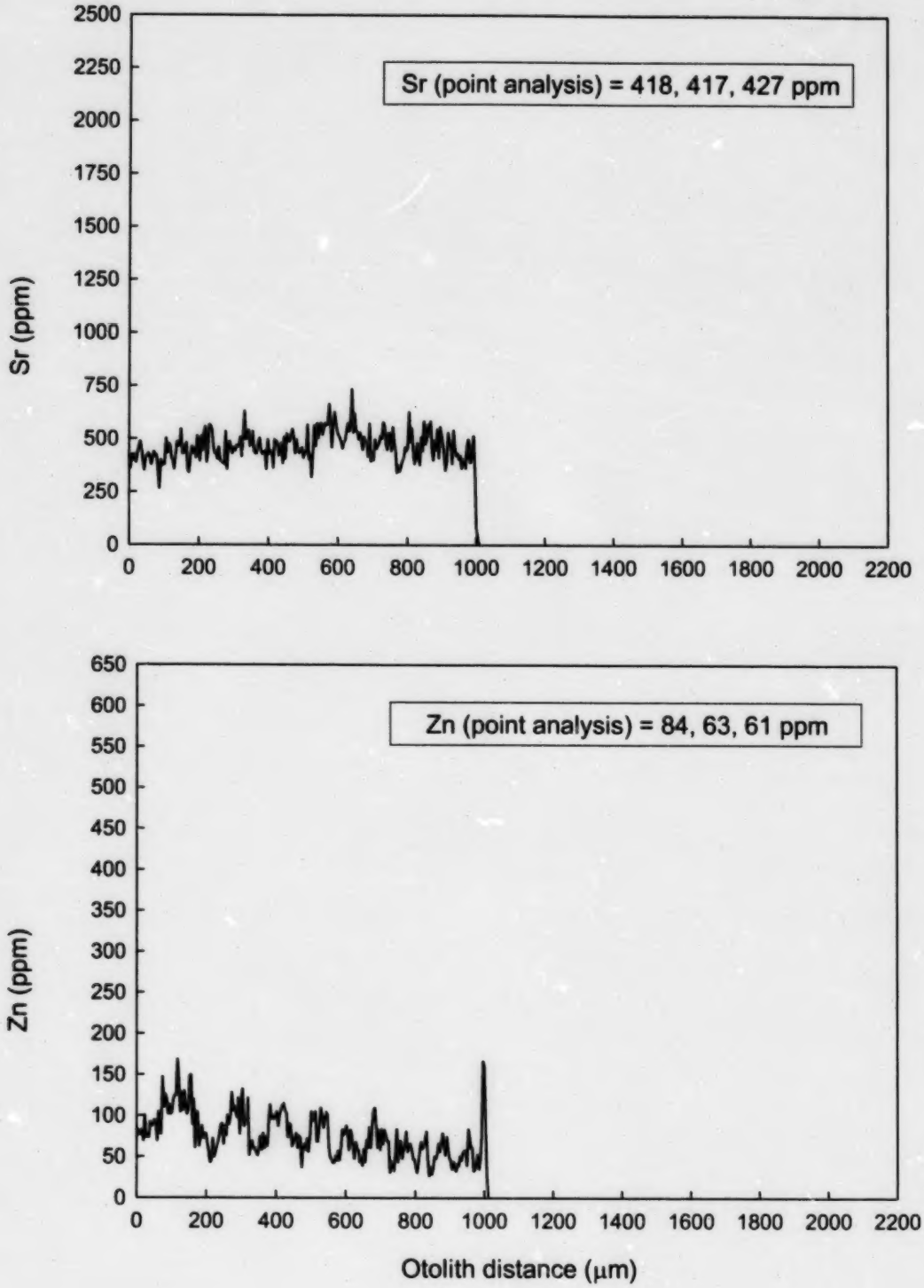

Fig. 108. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (336 mm, 565 g, female, 11 yr) caught in Heintzelman Lake, May/June 1995. Point analysis results are also indicated.

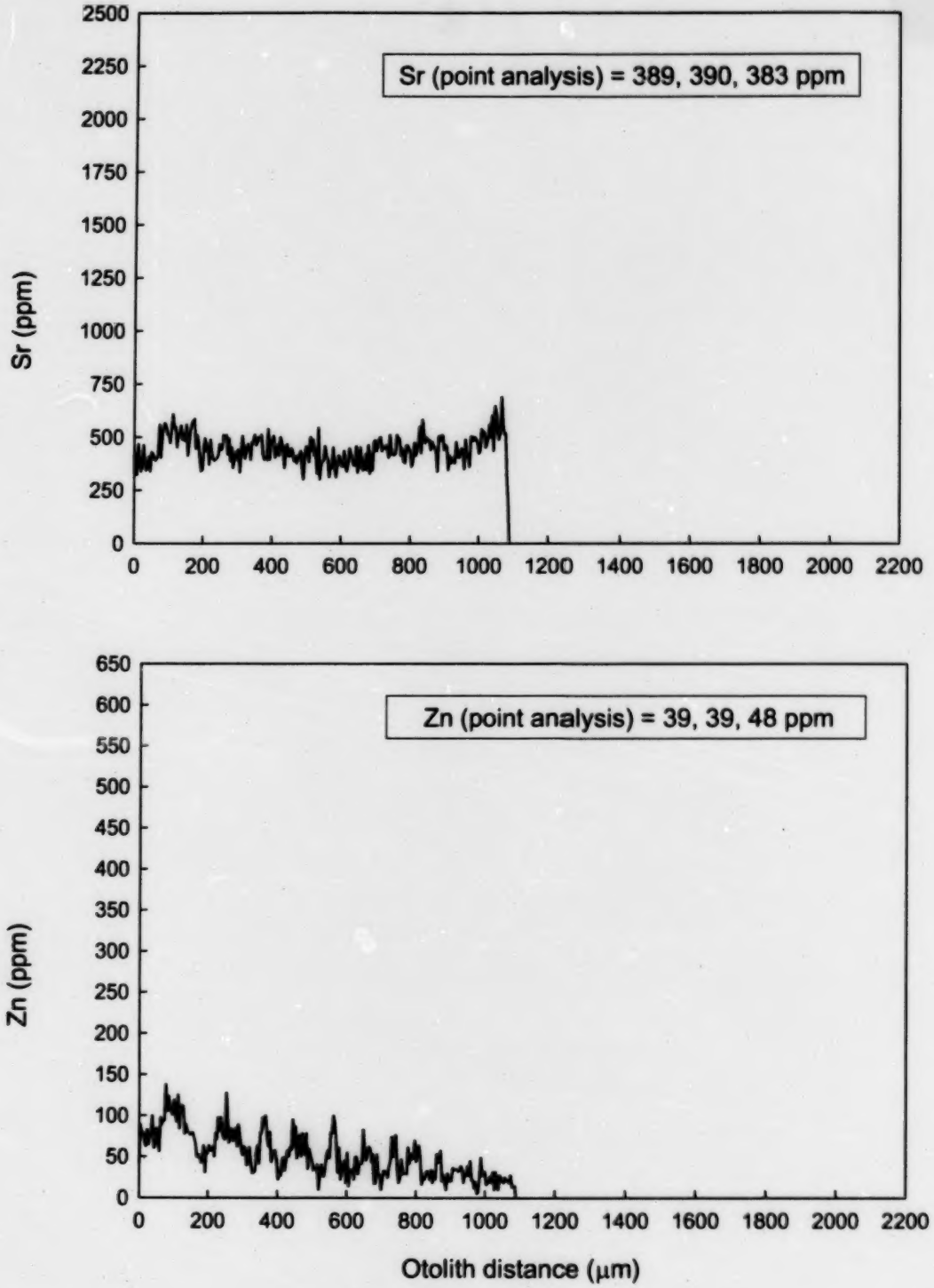

Fig. 109. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (268 mm, 167 g, female, 17 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

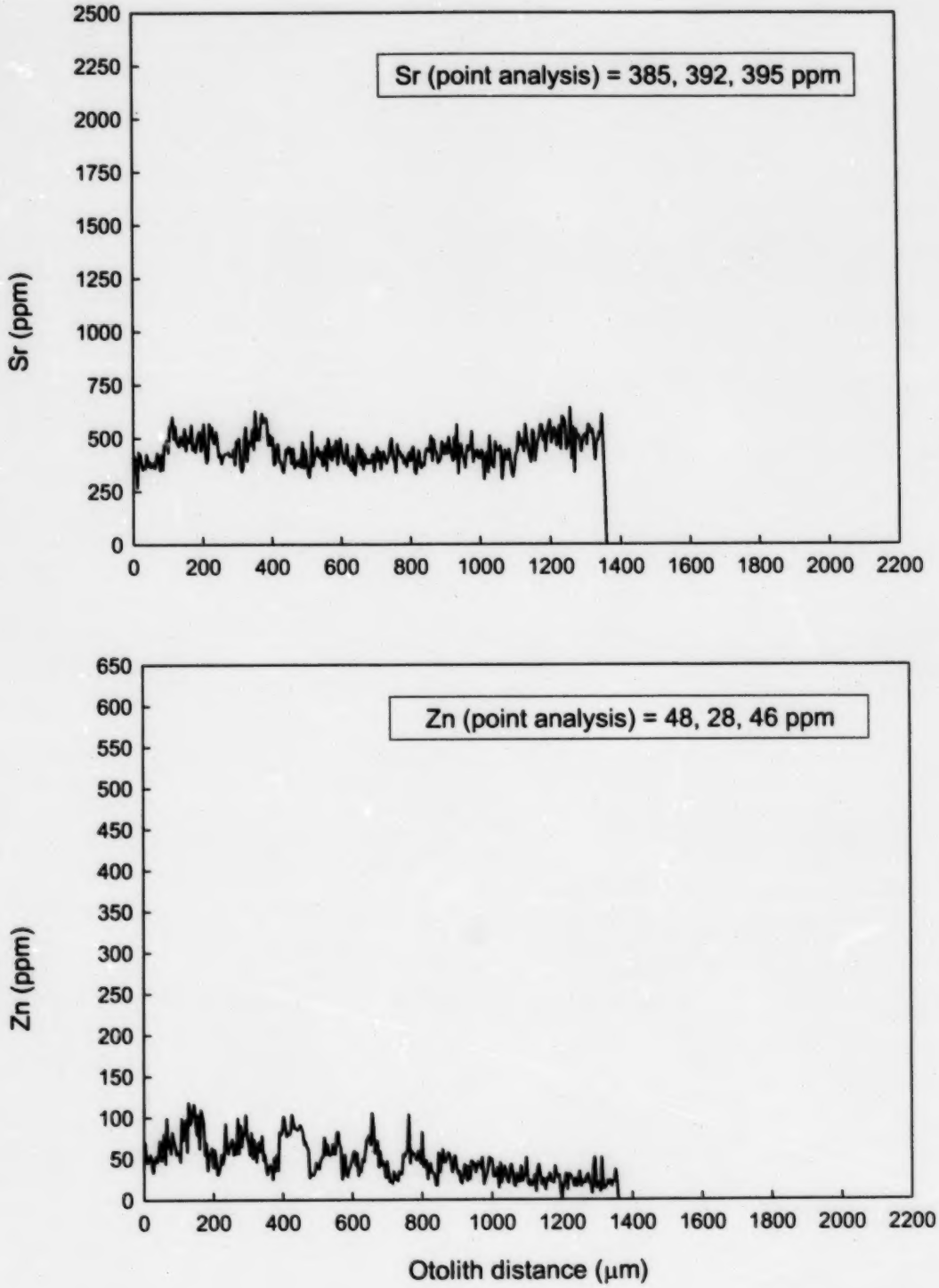

Fig. 110. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (292 mm, 165 g, female, 22 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

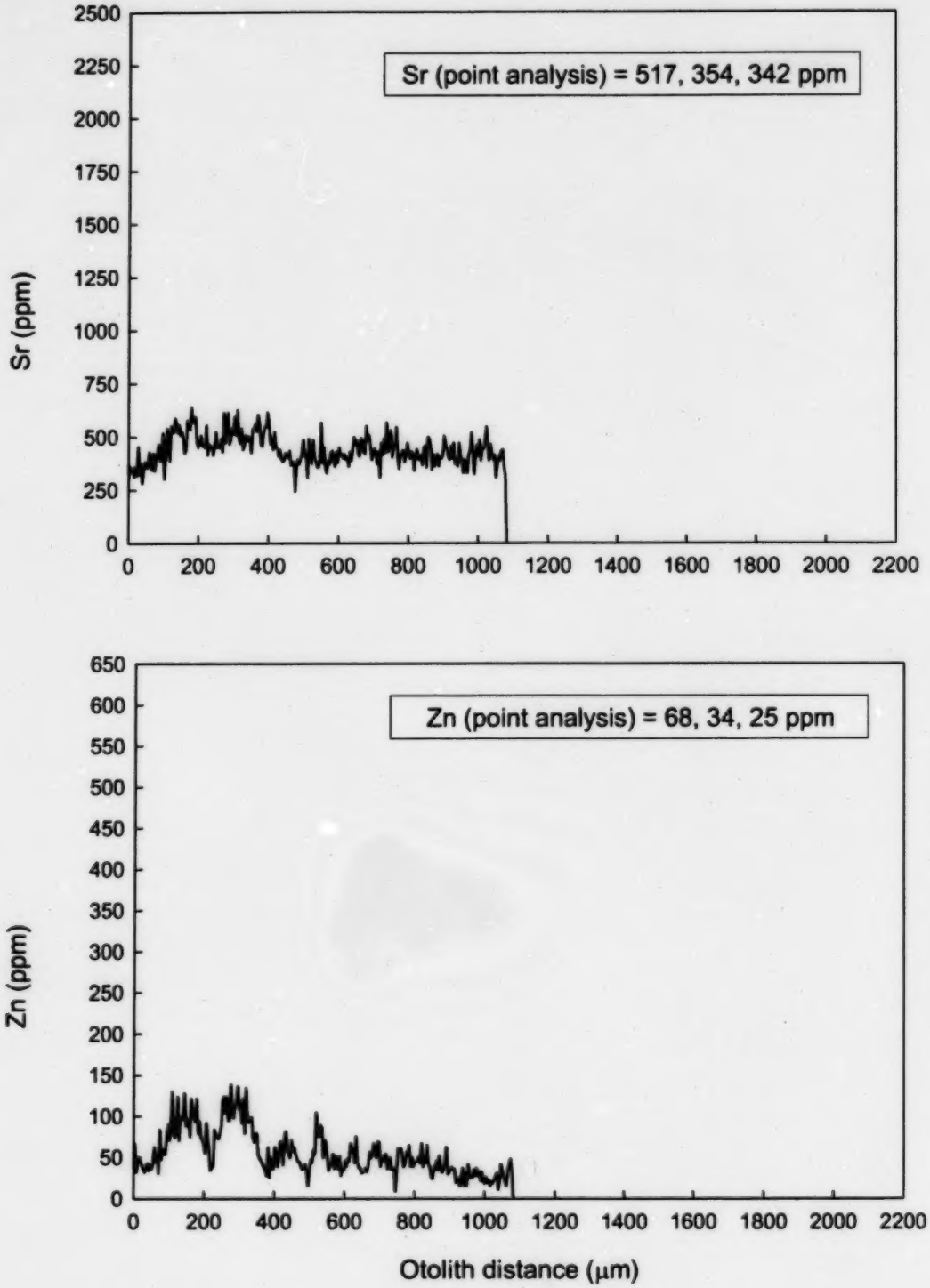

Fig. 111. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (275 mm, 197 g, female, 15 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

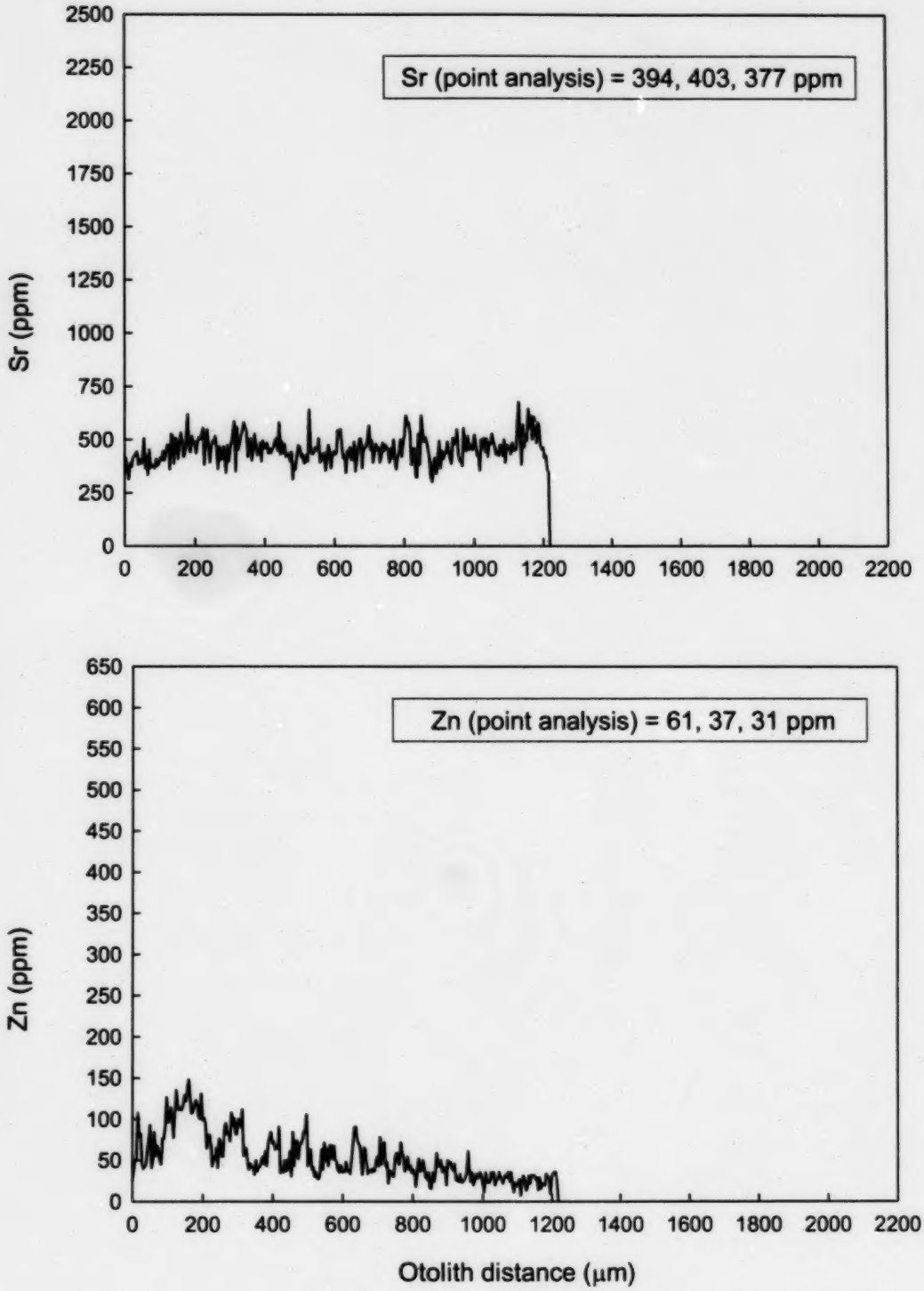

Fig. 112. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (308 mm, 283 g, male, 22 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

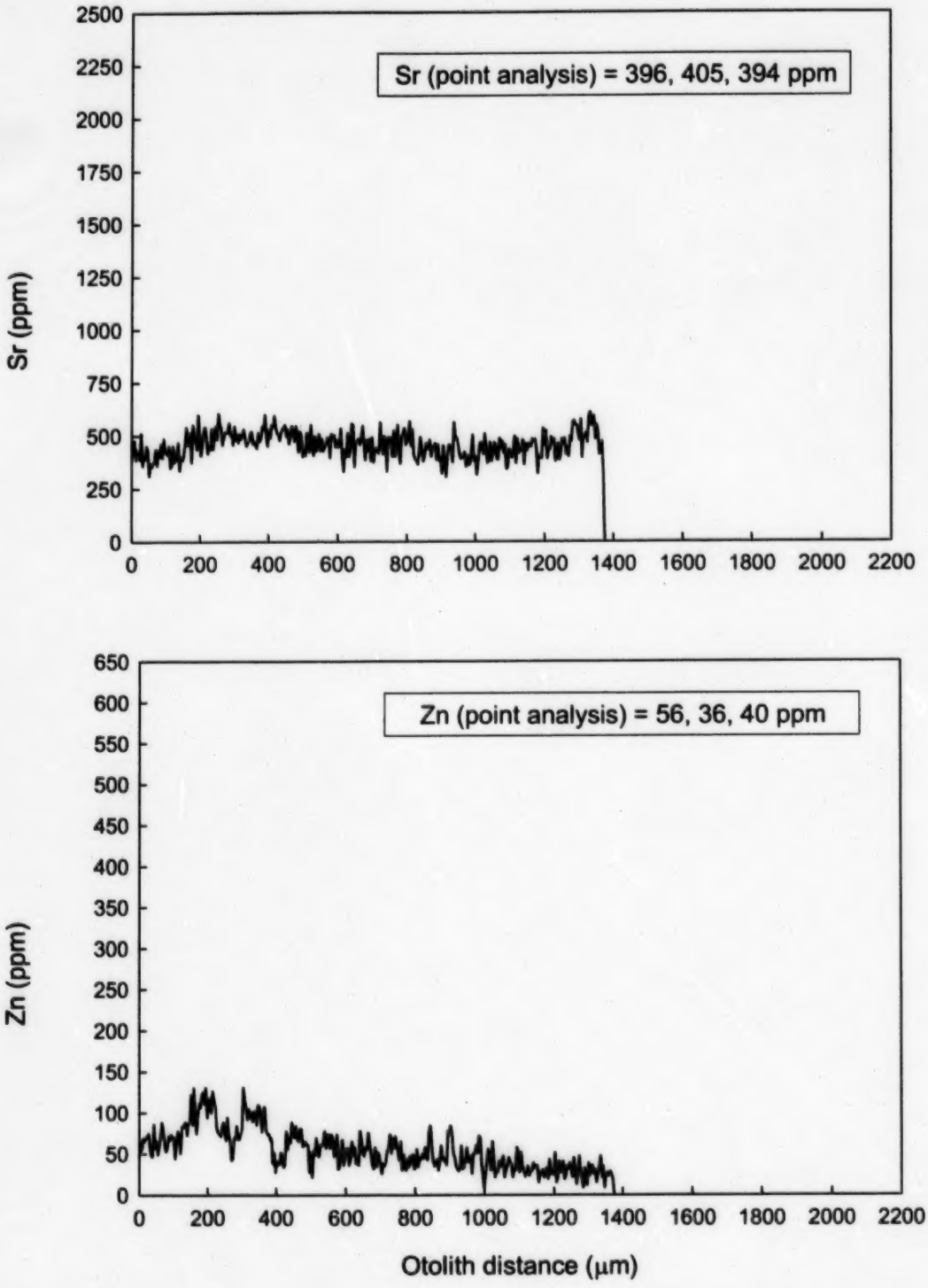

Fig. 113. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (310 mm, 252 g, male, 19 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

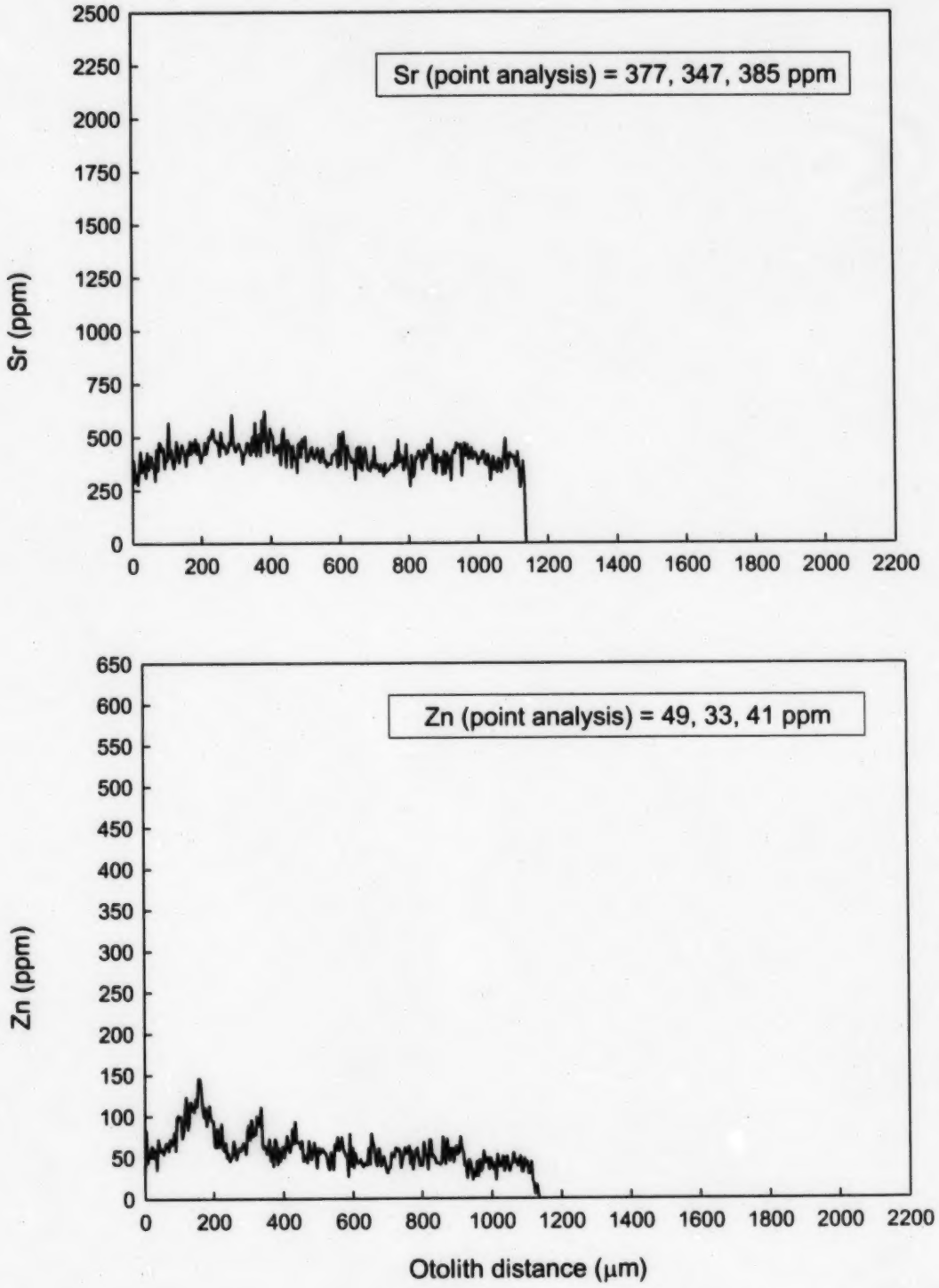

Fig. 114. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (277 mm, 200 g, female, 20 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

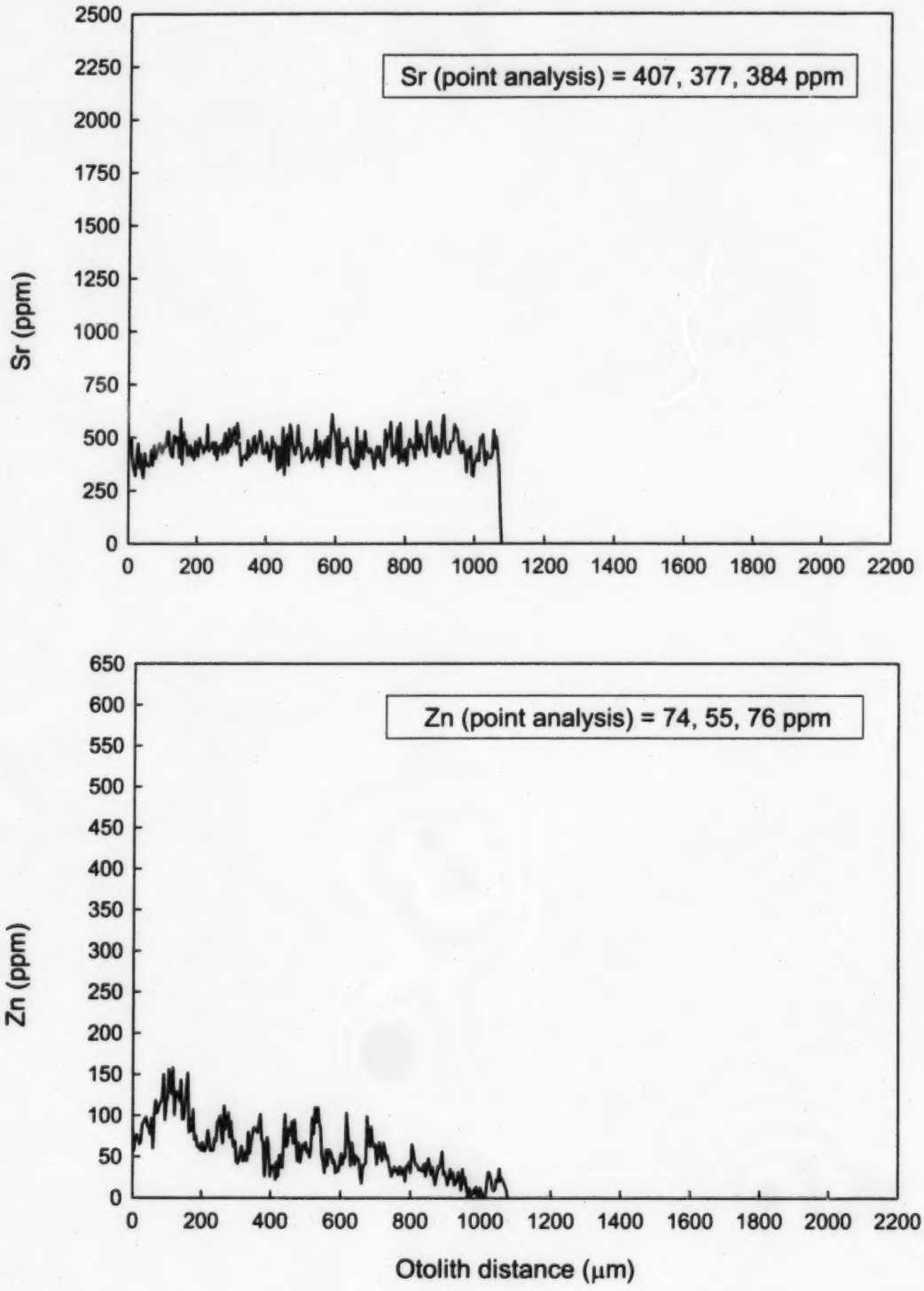

Fig. 115. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (293 mm, 218 g, male, 19 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

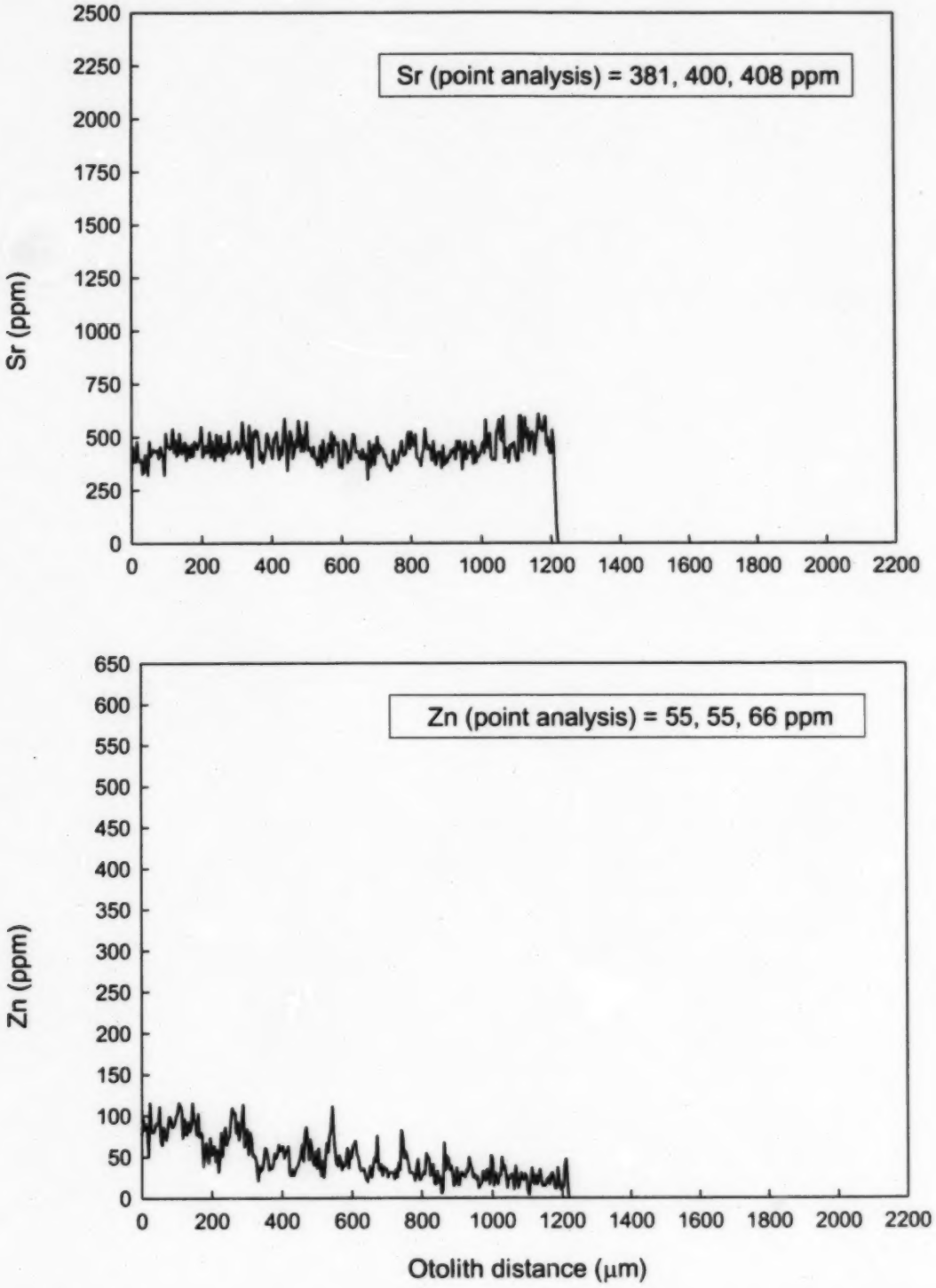

Fig. 116. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (283 mm, 223 g, male, 18 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

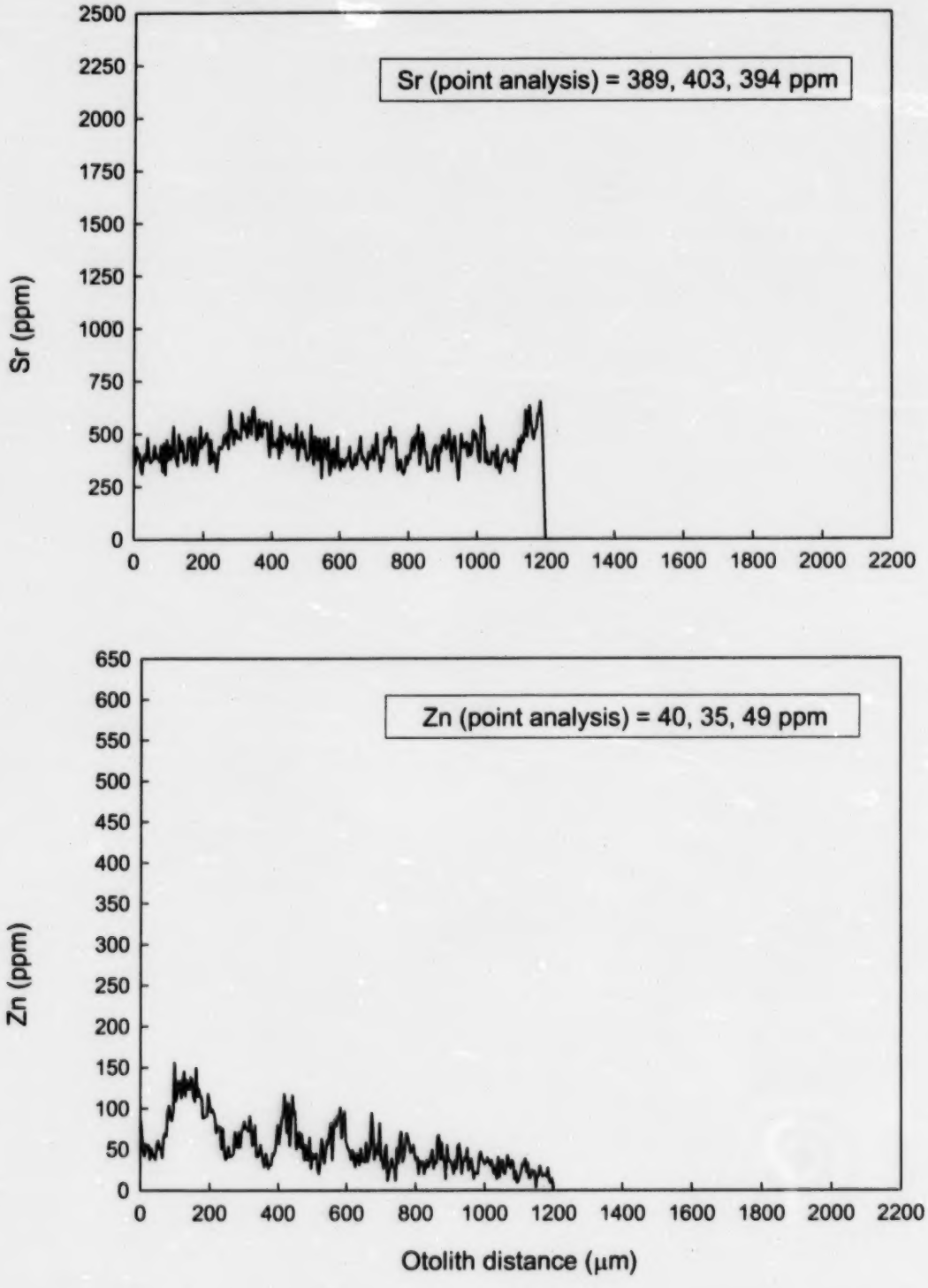

Fig. 117. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (264 mm, 177 g, female, 16 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

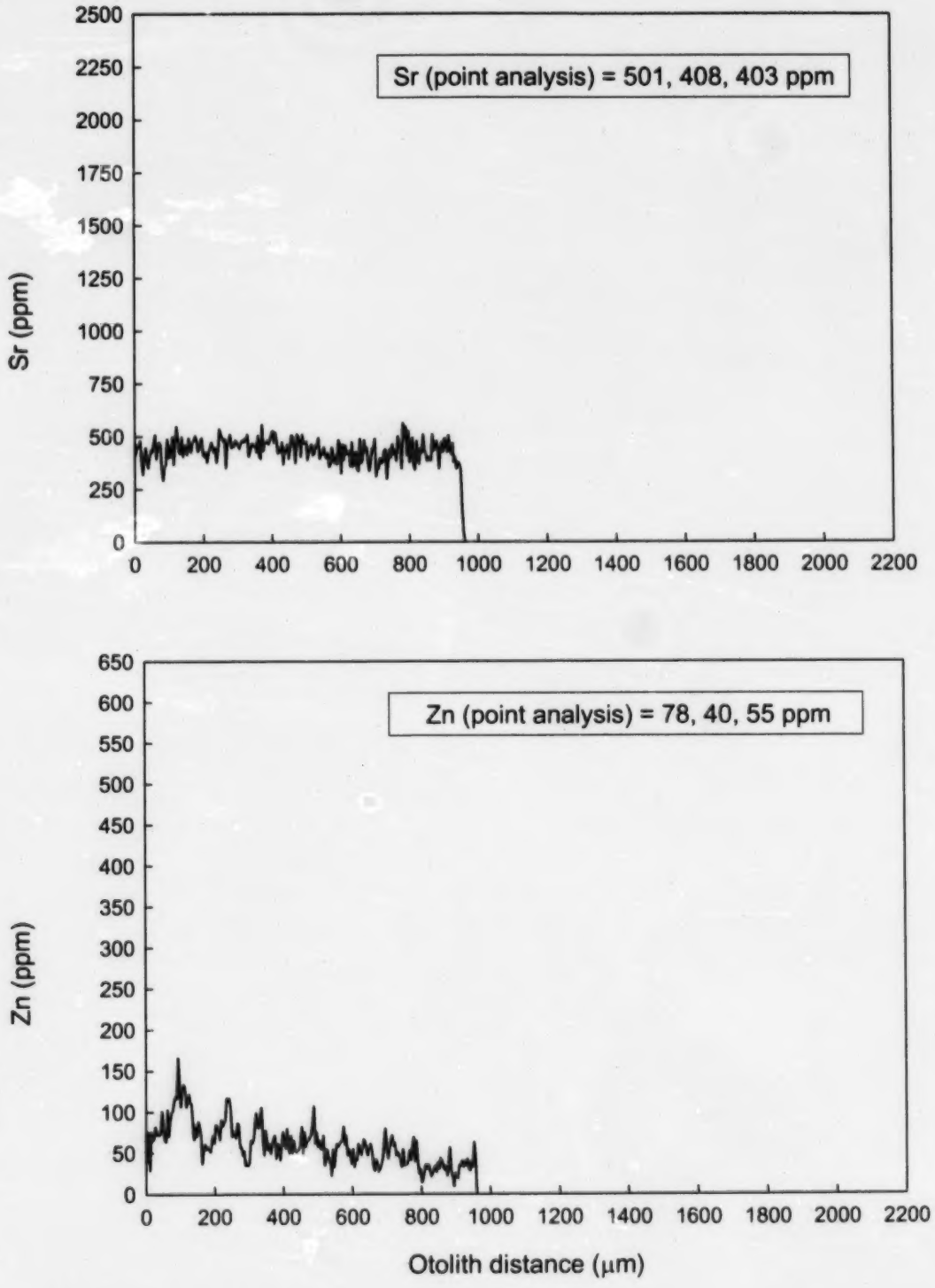

Fig. 118. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (260 mm, 171 g, male, 13 yr) caught in Kilbourne Lake, May 1996. Point analysis results are also indicated.

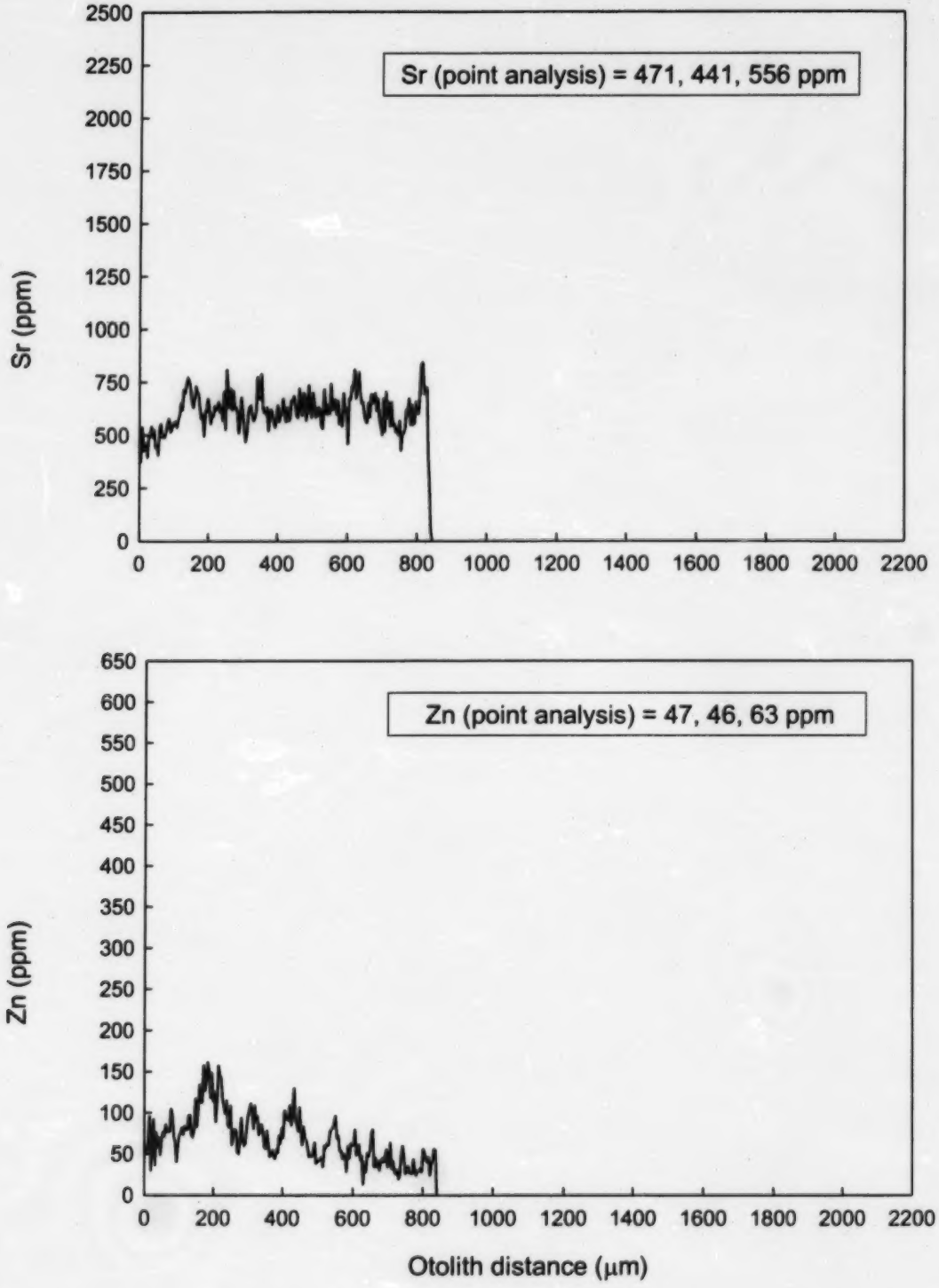

Fig. 119. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (158 mm, 54 g, male, 10 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

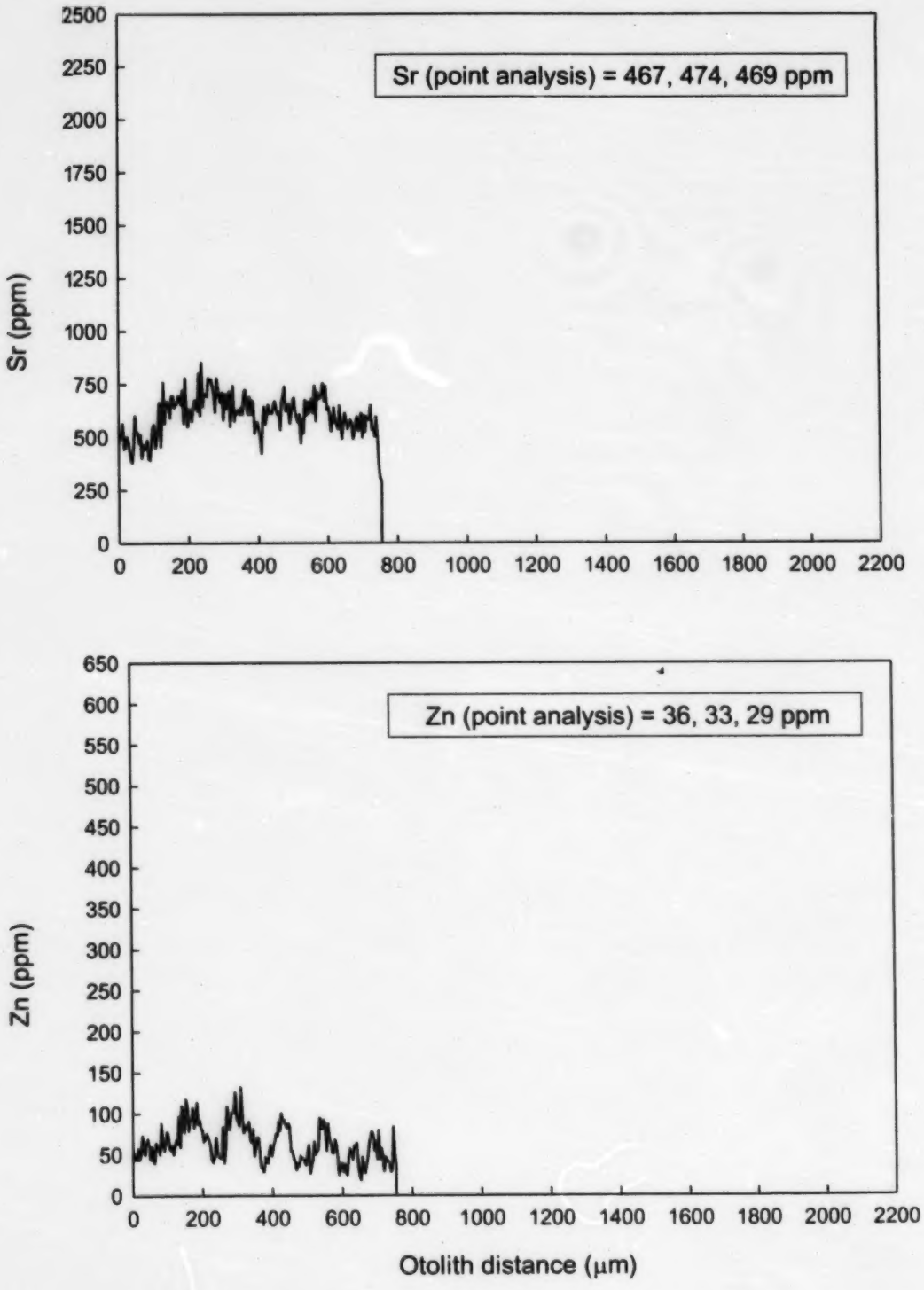

Fig. 120. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (124 mm, 26 g, male, 6 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

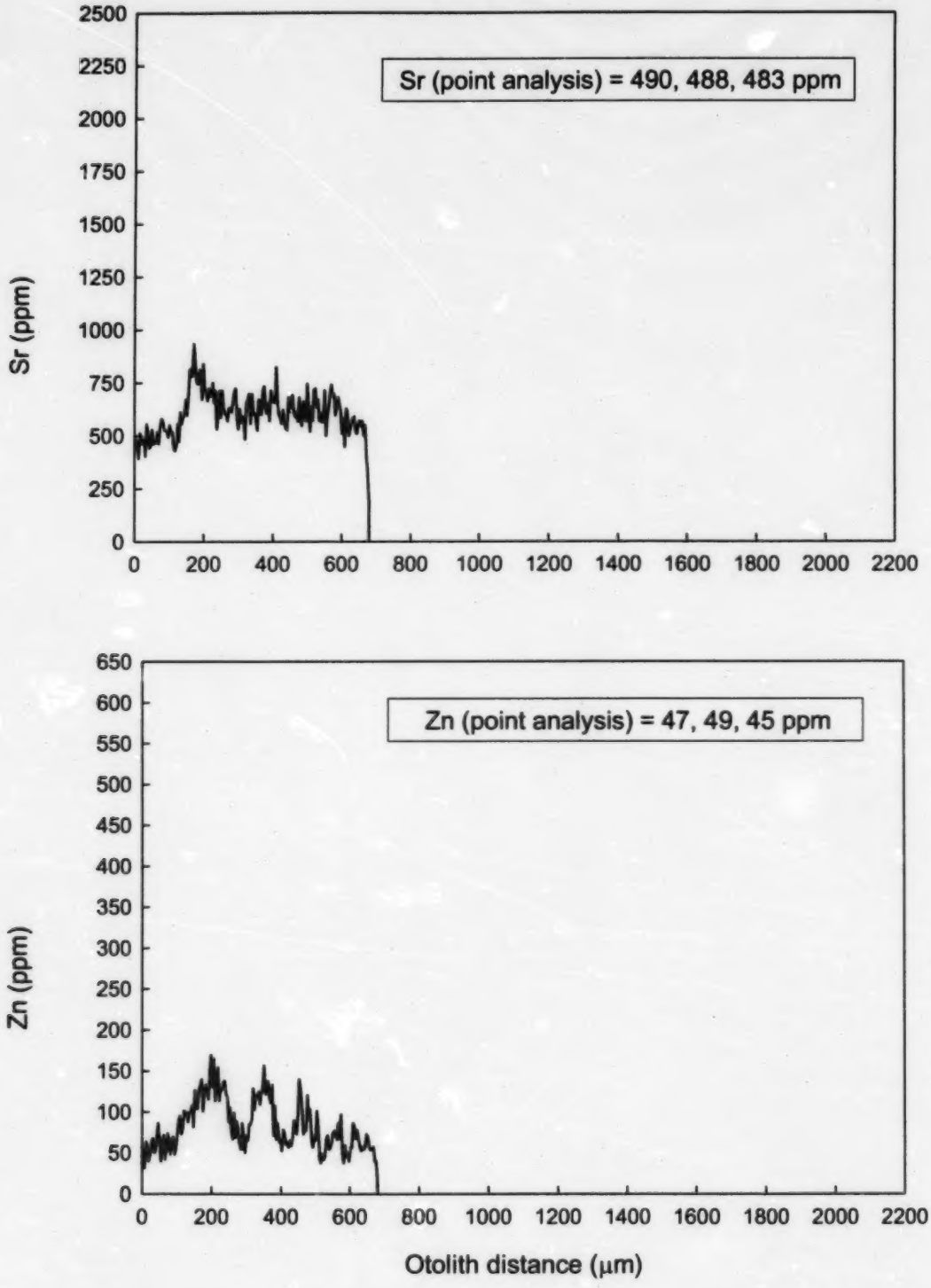

Fig. 121. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (134 mm, 33 g, female, 5 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

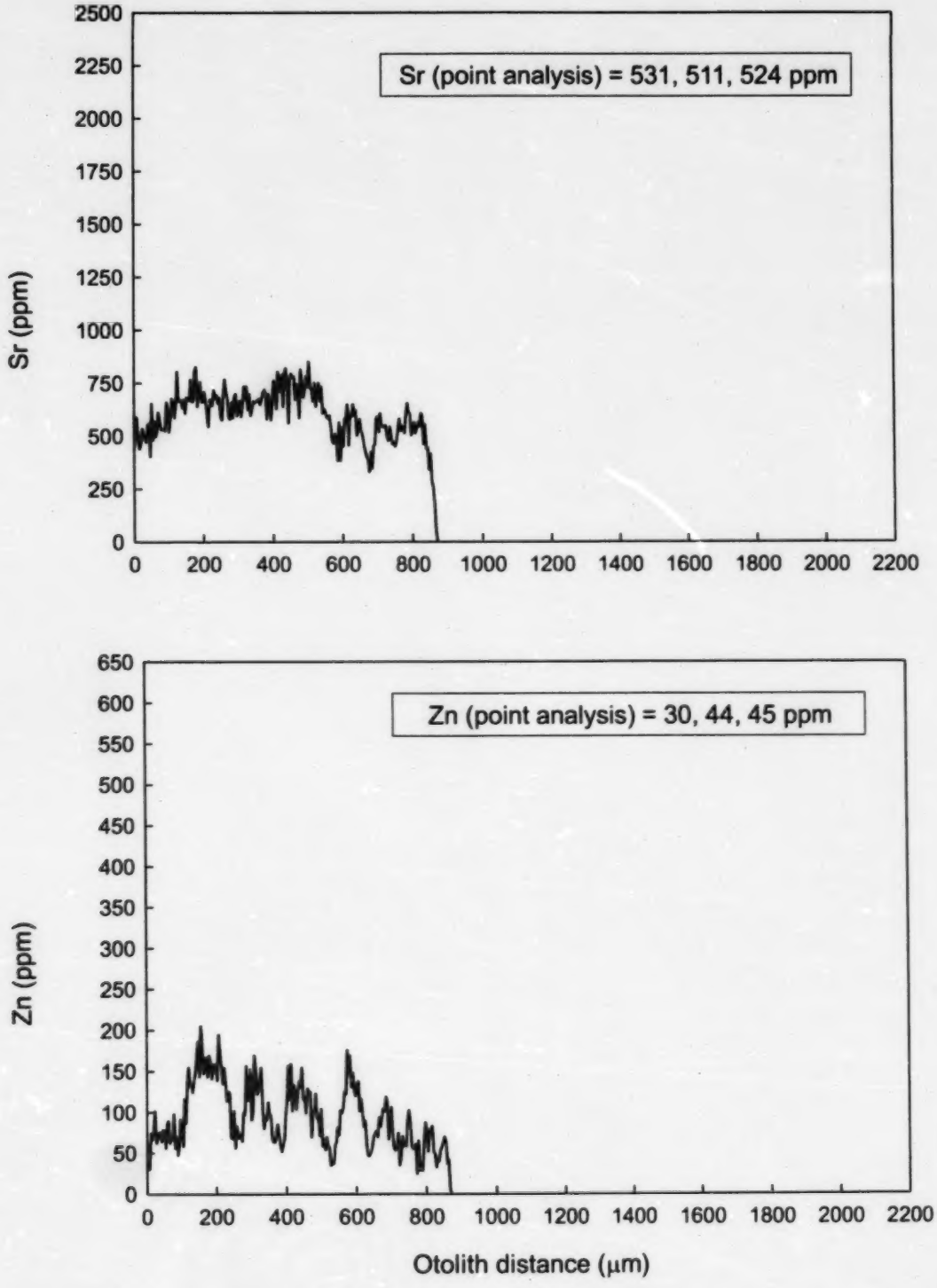

Fig. 122. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (161 mm, 47 g, male, 7 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

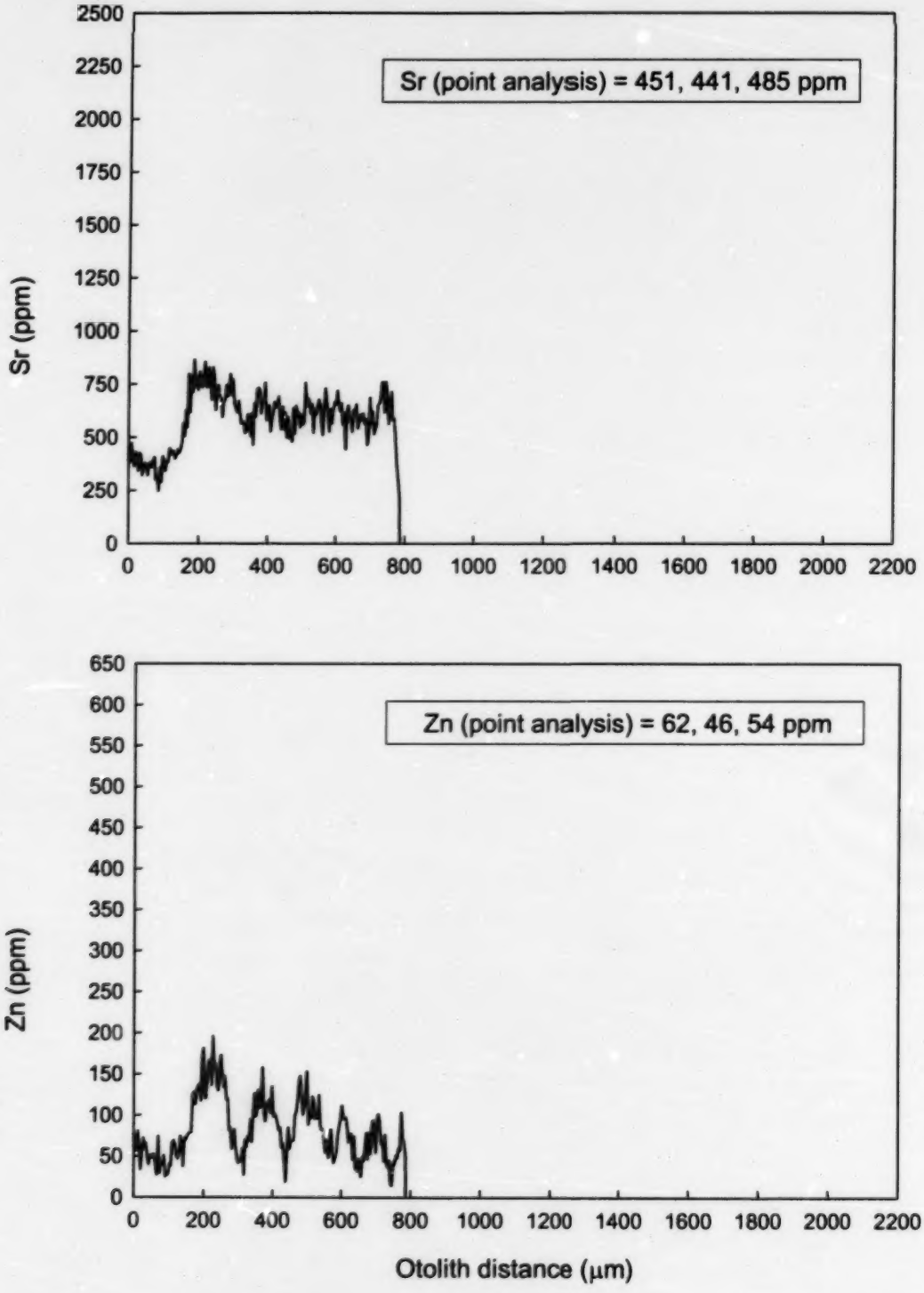

Fig. 123. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (145 mm, 42 g, female, 5 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

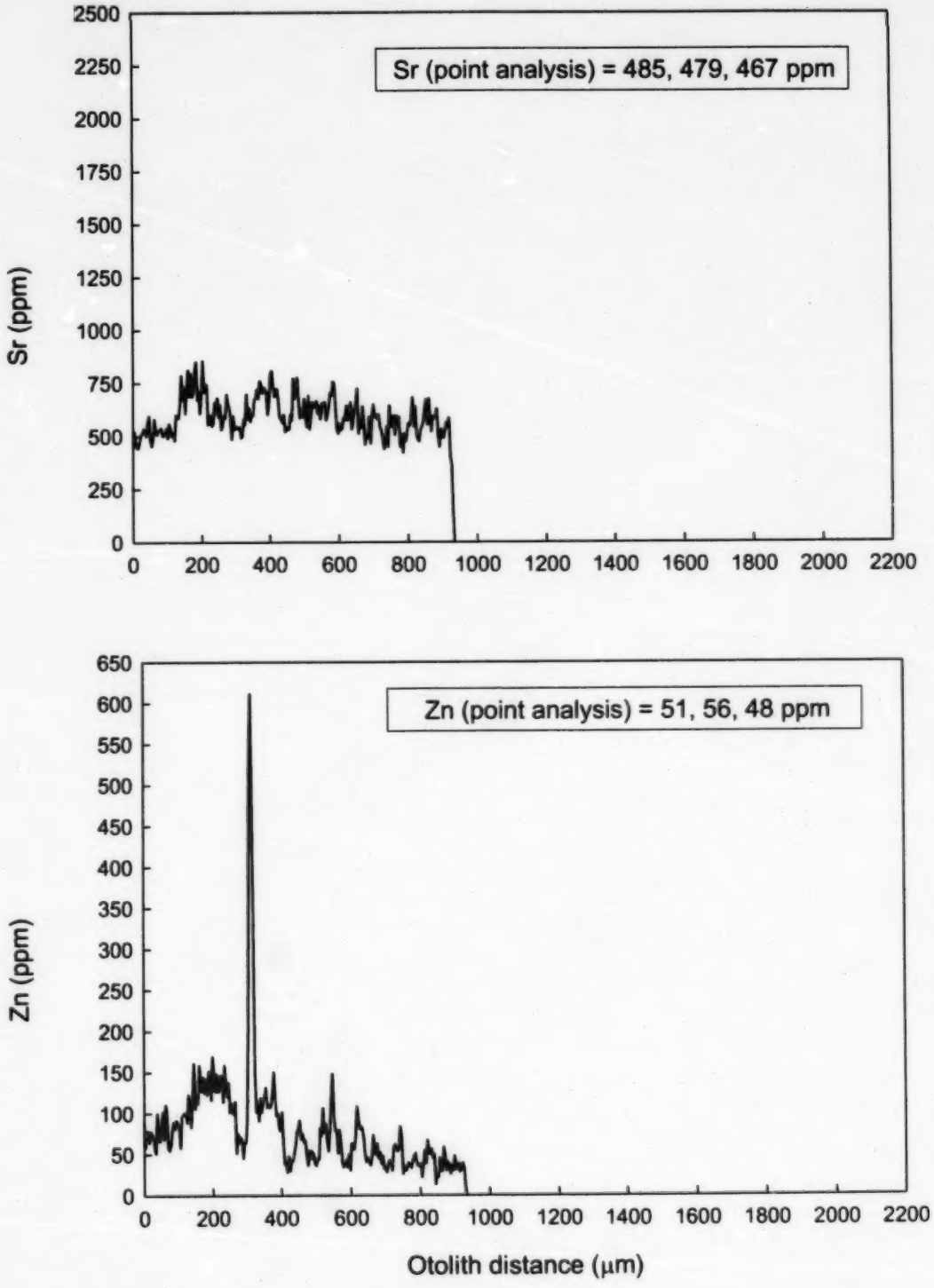

Fig. 124. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (153 mm, 46 g, male, 11 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

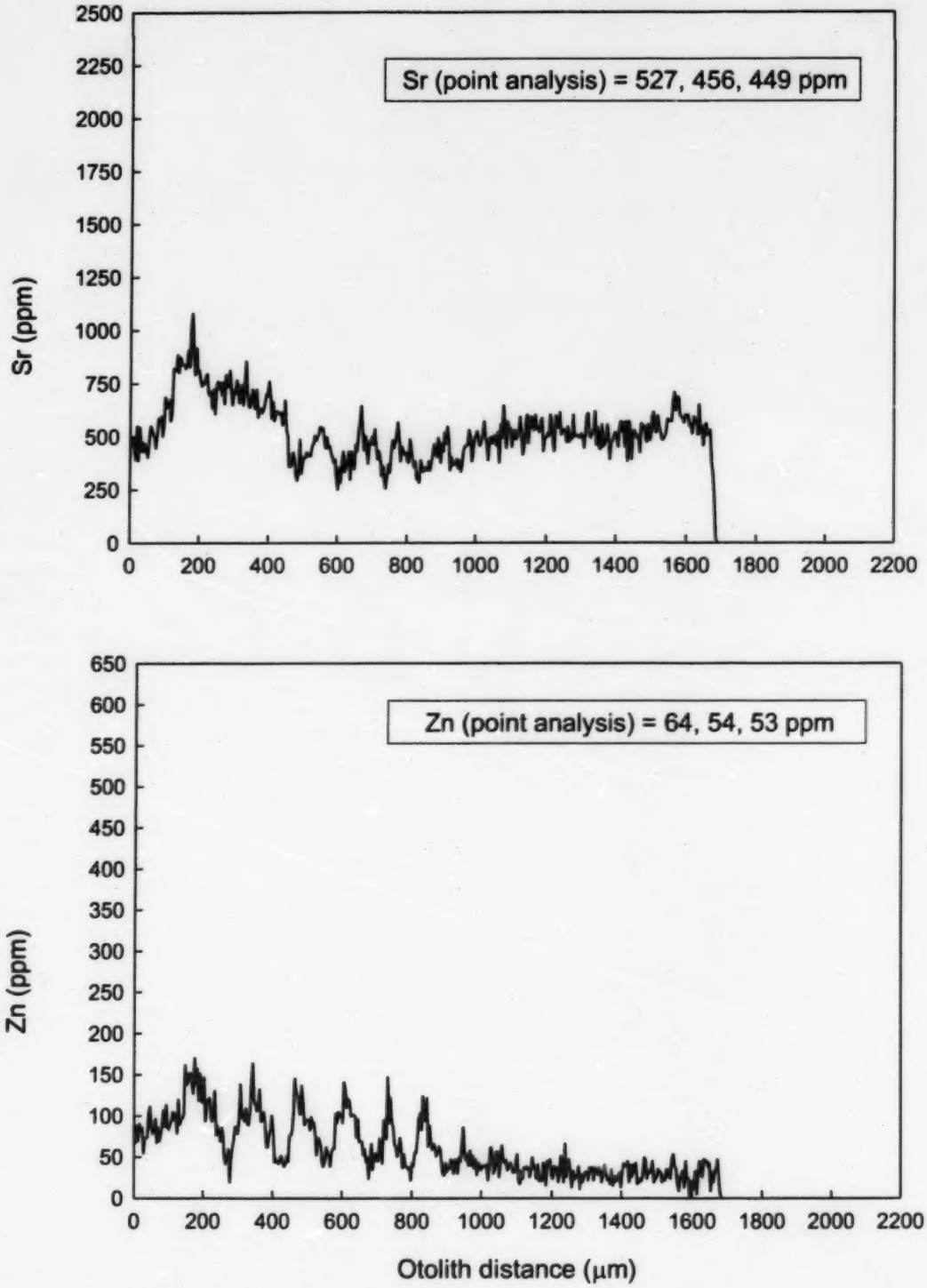

Fig. 125. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (539 mm, 1949 g, male, 18 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

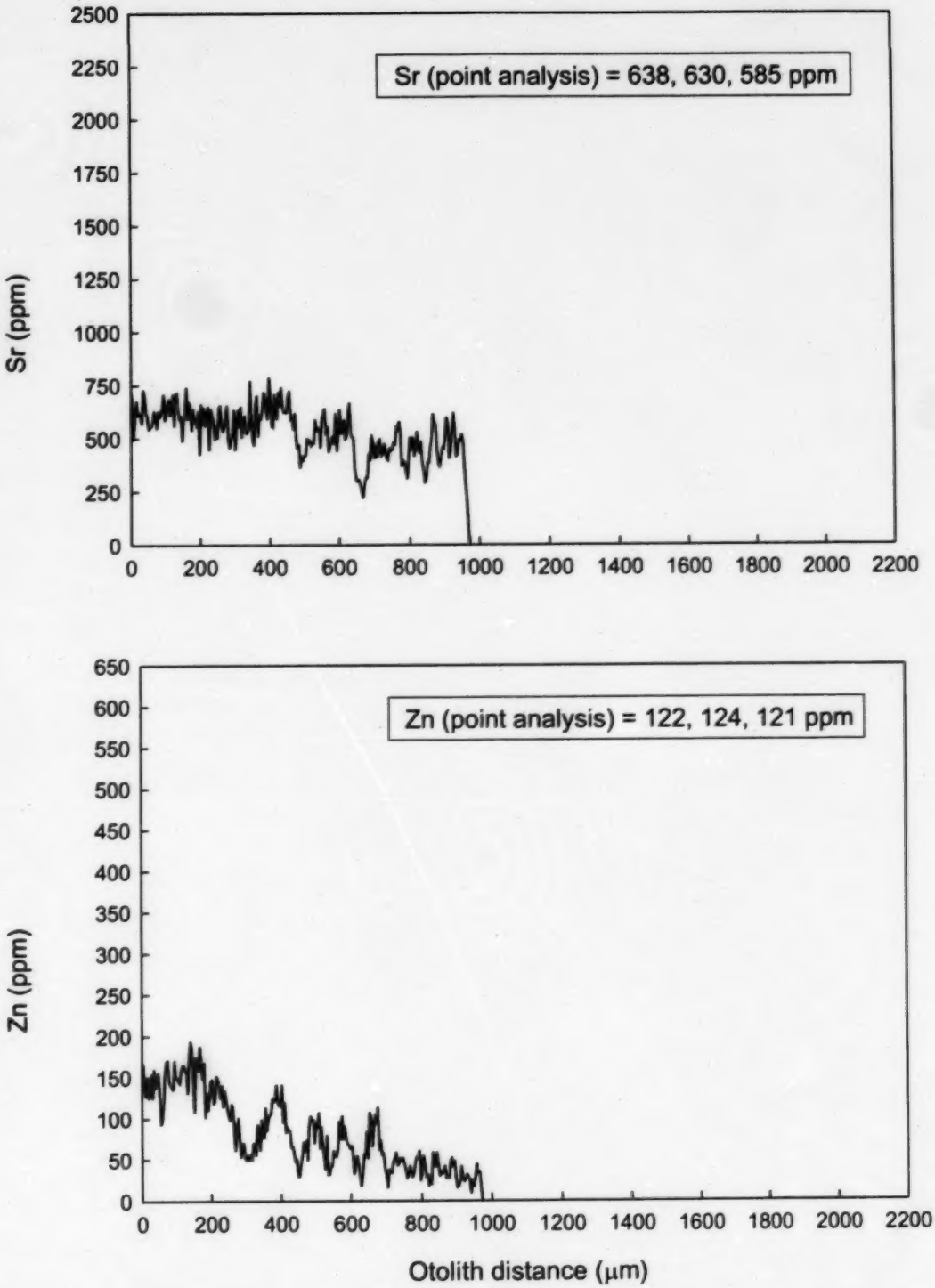

Fig. 126. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (168 mm, 47 g, female, 11 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

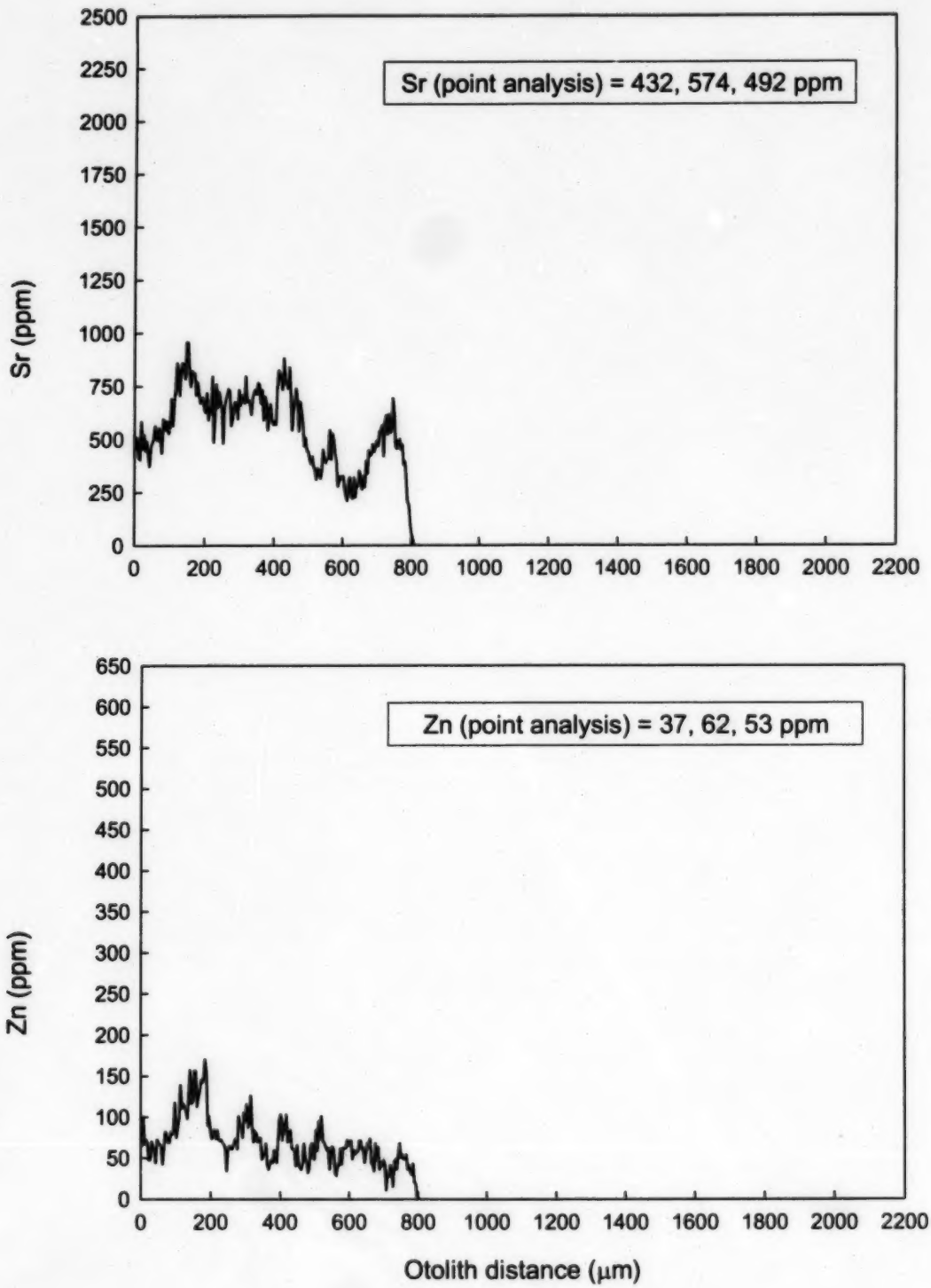

Fig. 127. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (176 mm, 53 g, female, 7 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

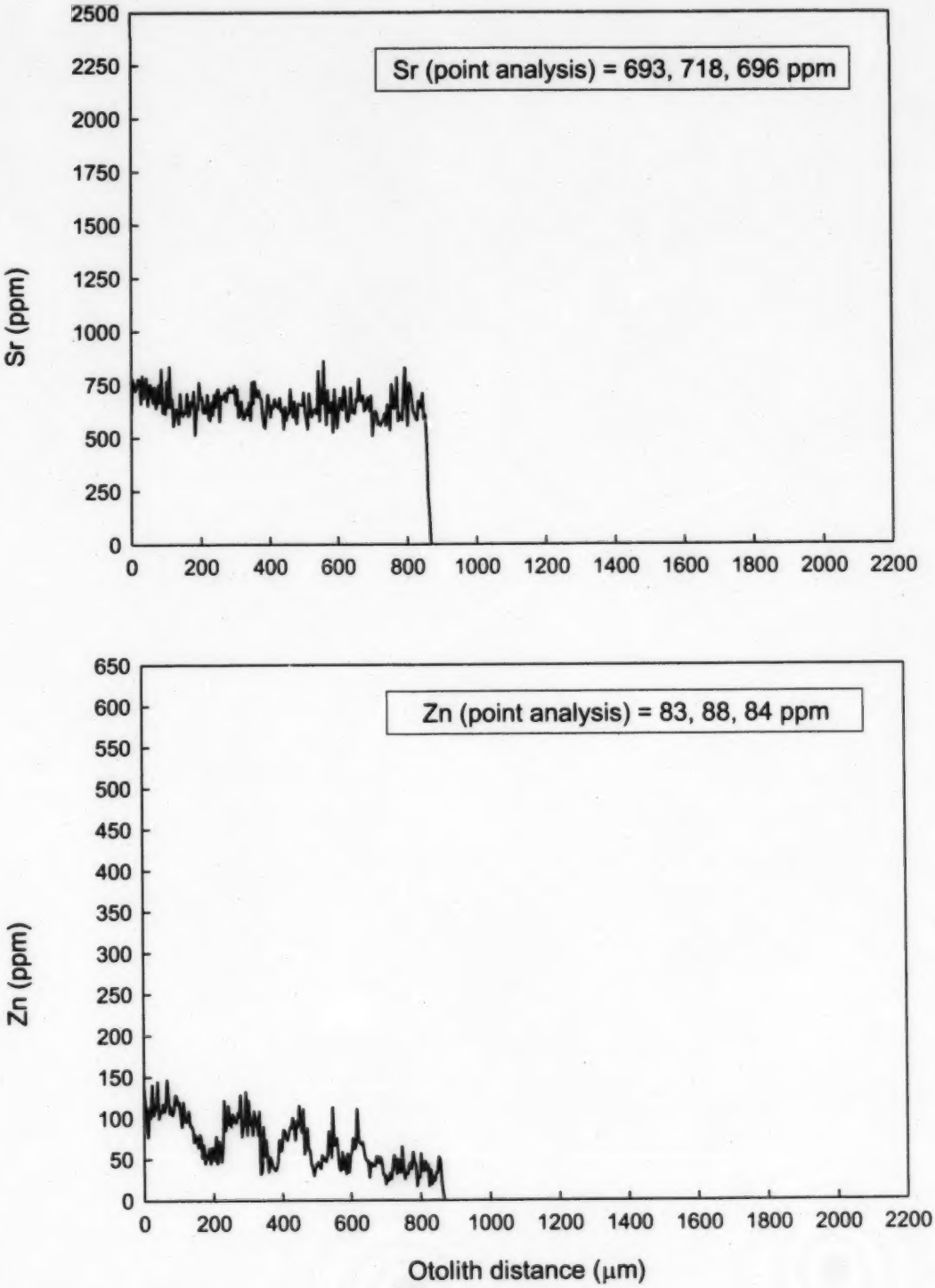

Fig. 128. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (153 mm, 46 g, female, 9 yr) caught in Lewis Lake, July 1998. Point analysis results are also indicated.

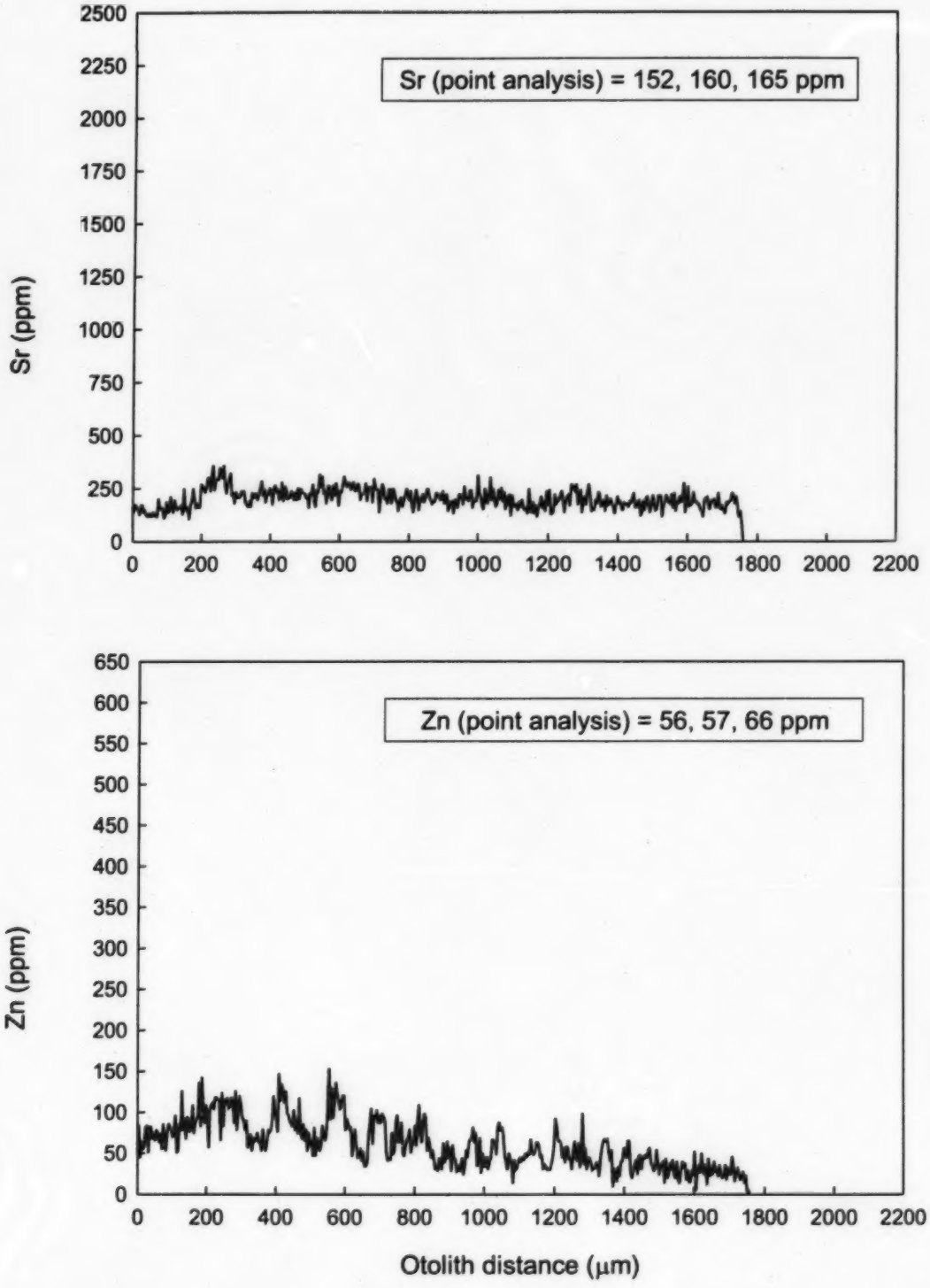

Fig. 129. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (590 mm, 1946 g, female, 24 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.

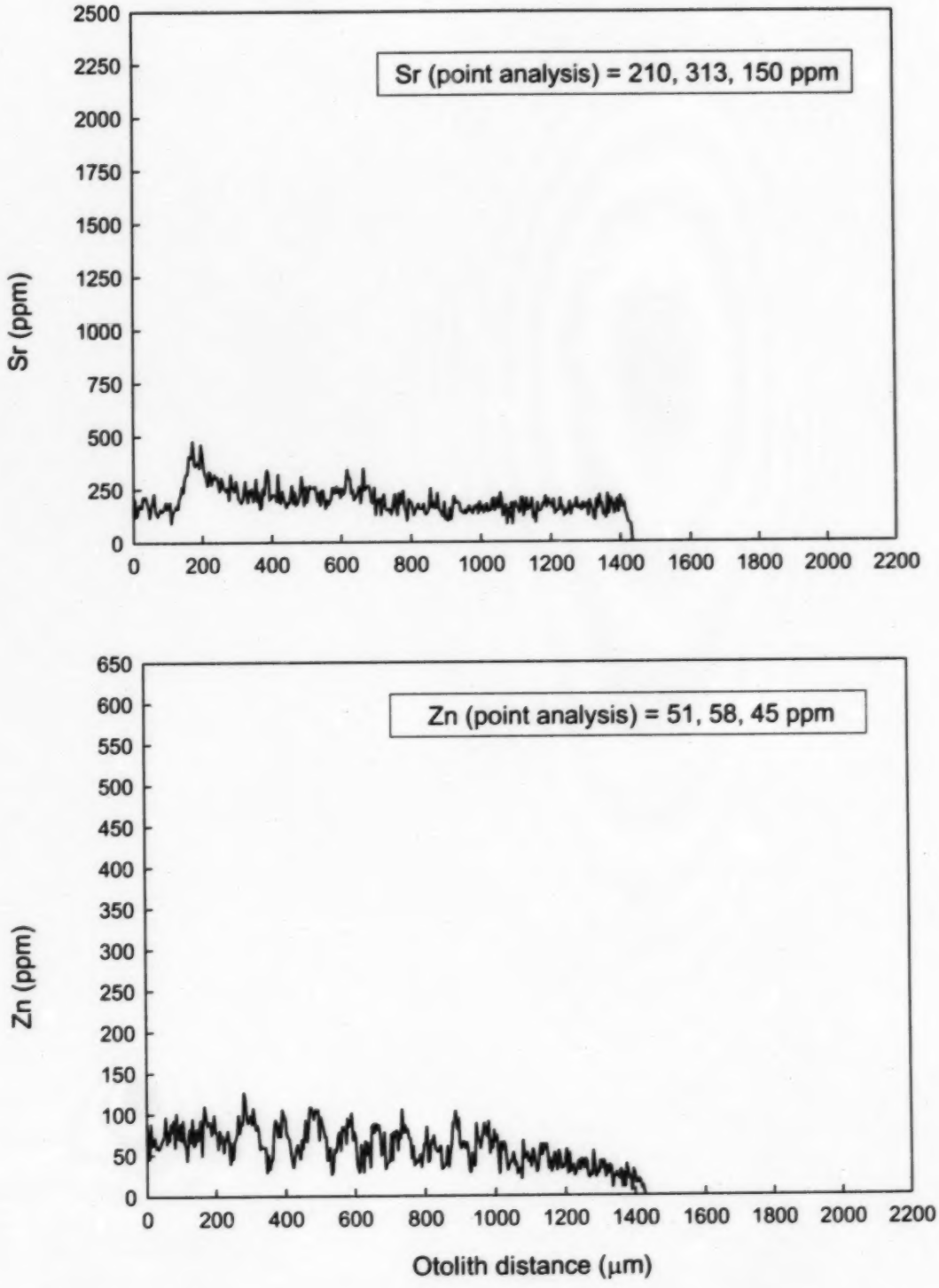

Fig. 130. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (630 mm, 2617 g, female, 20 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.

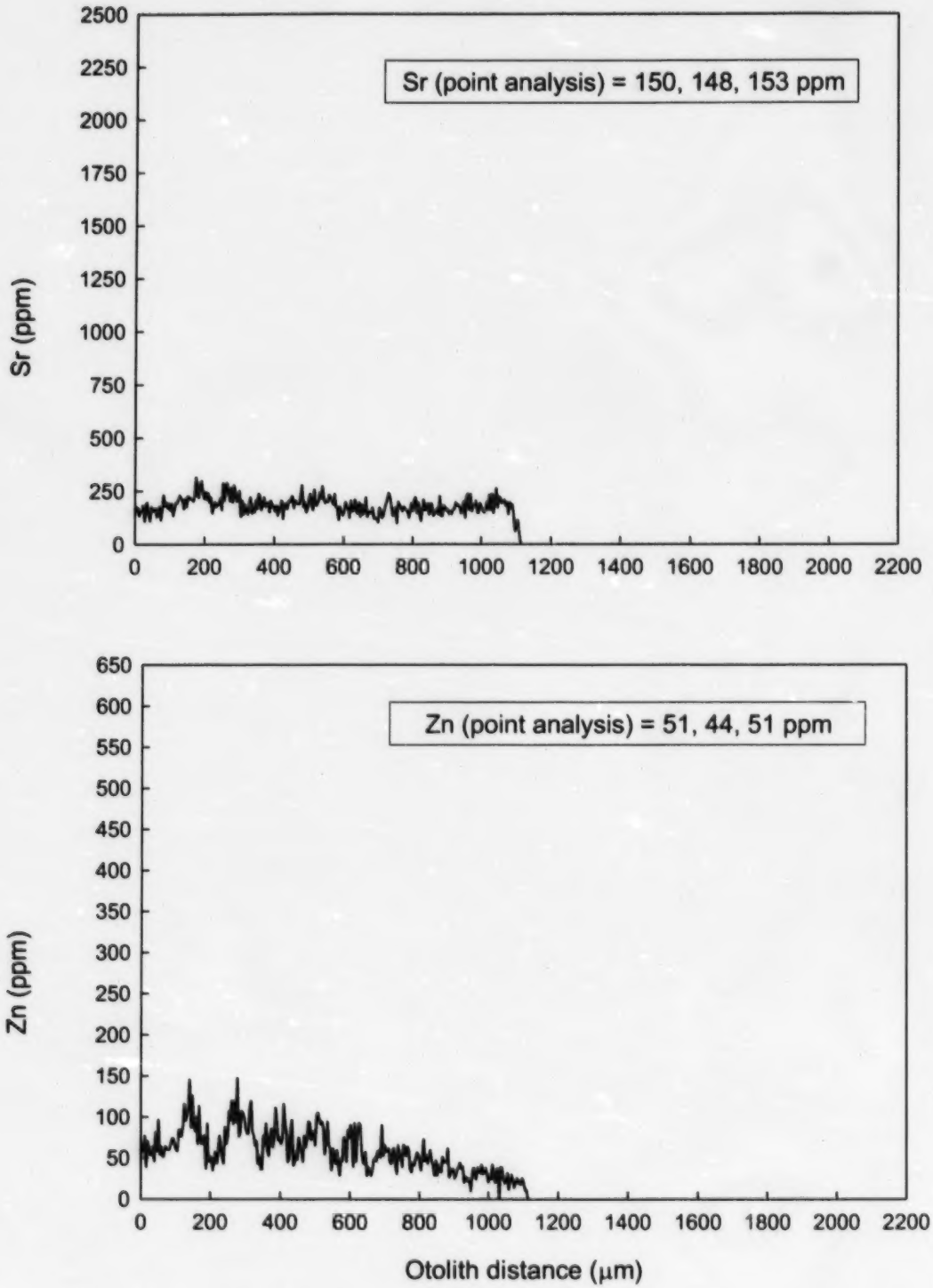

Fig. 131. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (196 mm, 63 g, female, 15 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.

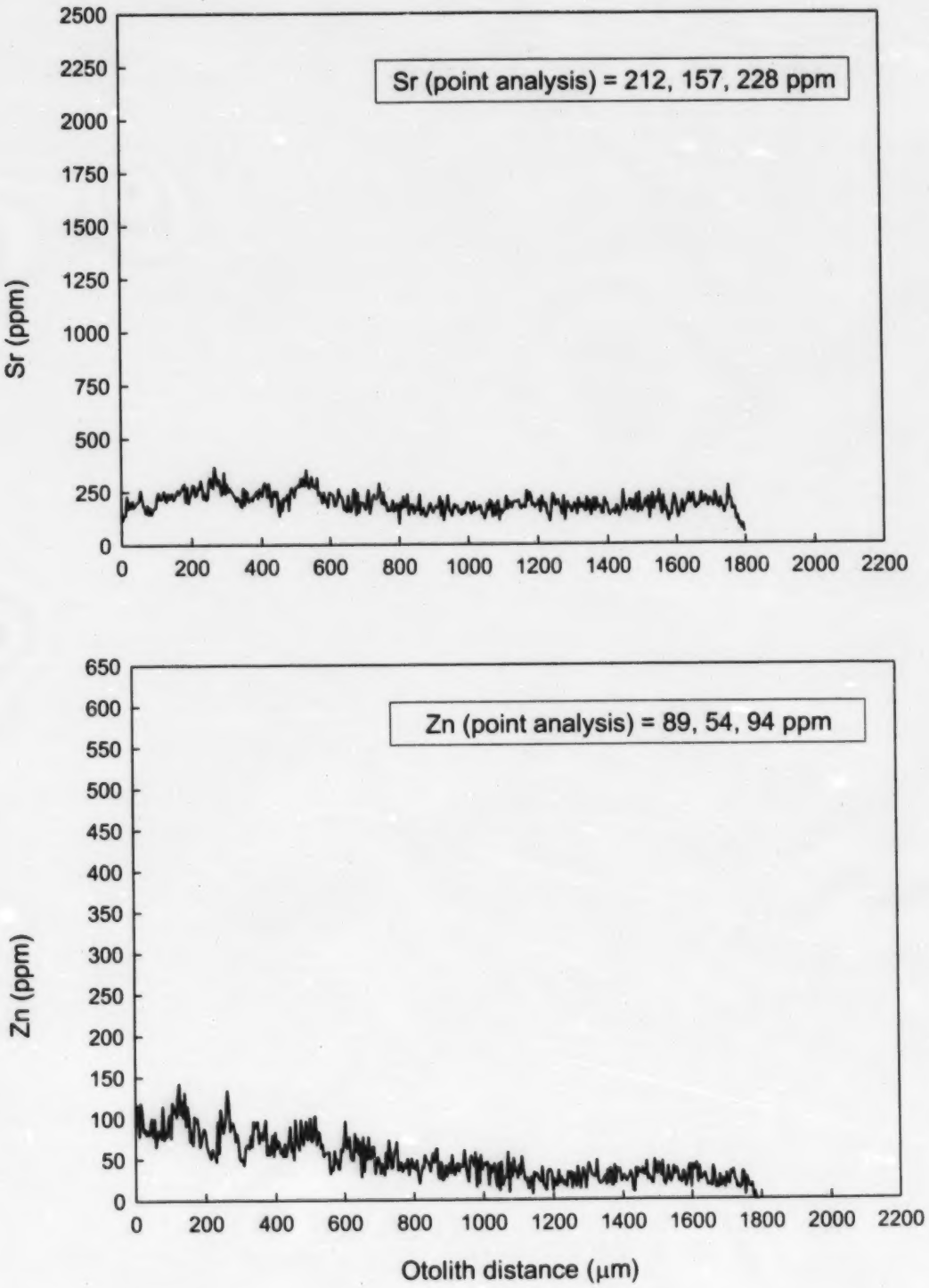

Fig. 132. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (669 mm, 2639 g, male, 30 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.

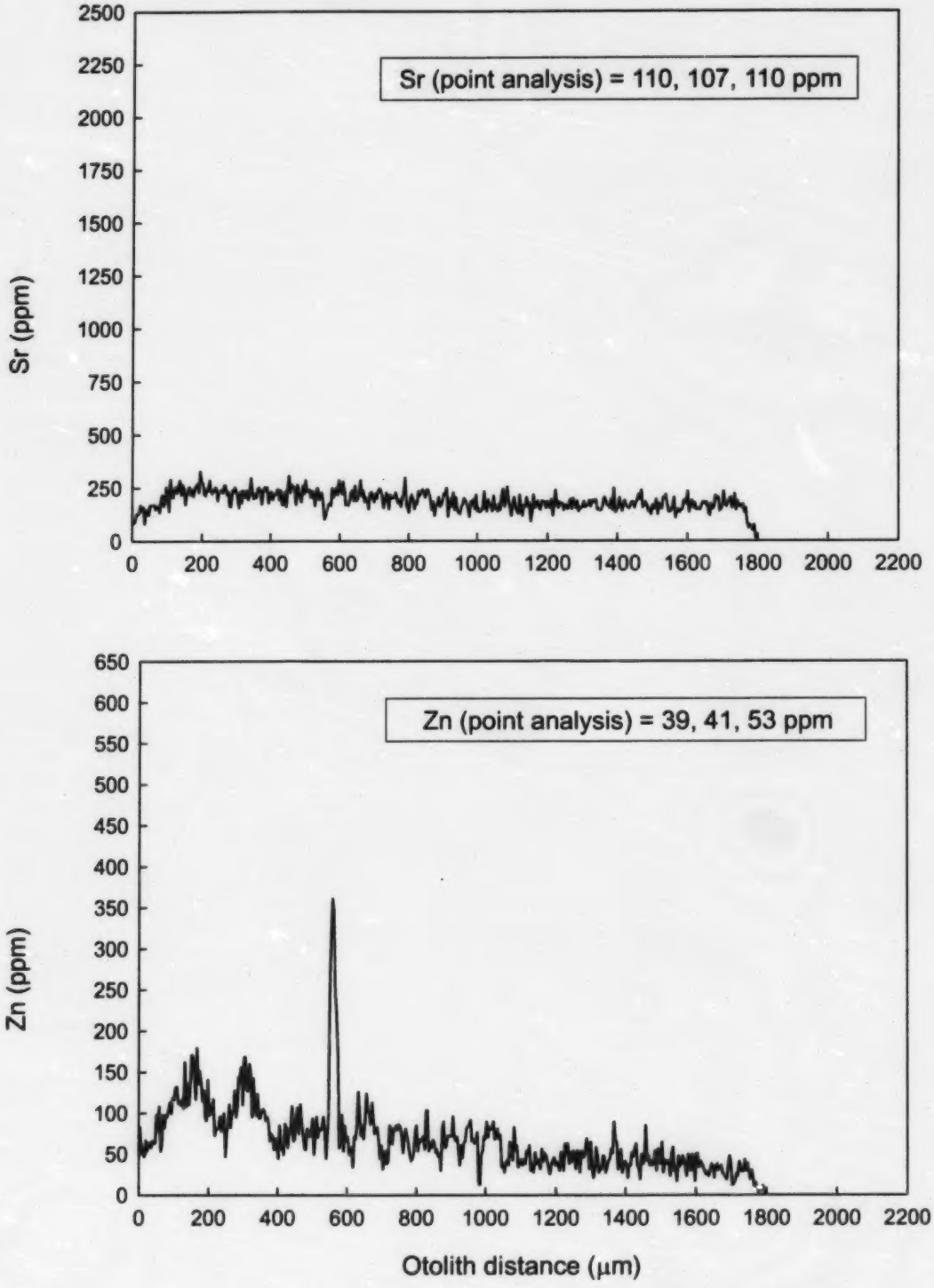

Fig. 133. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (529 mm, 1522 g, female, 27 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.

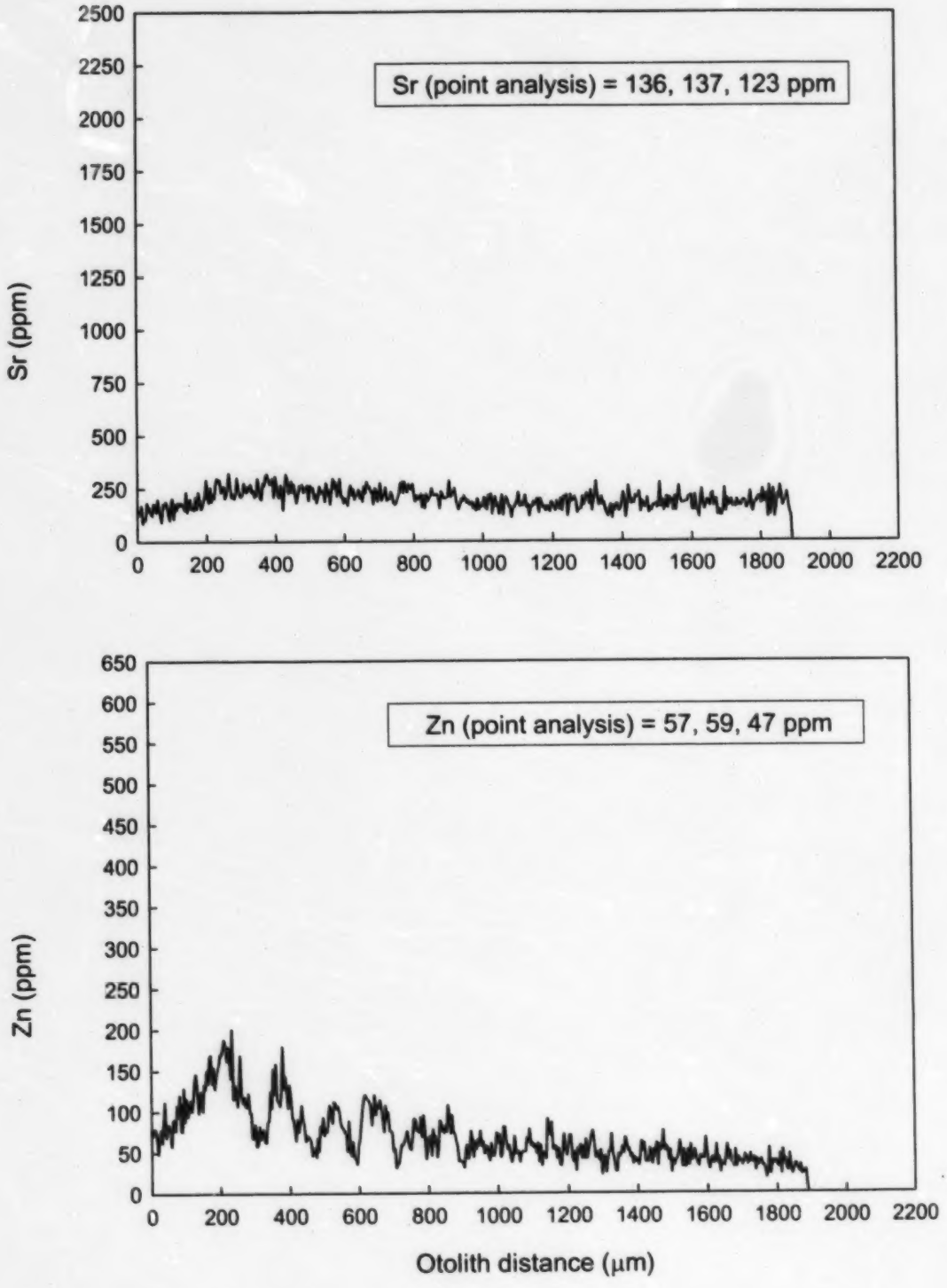

Fig. 134. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (635 mm, 1928 g, male, 27 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.

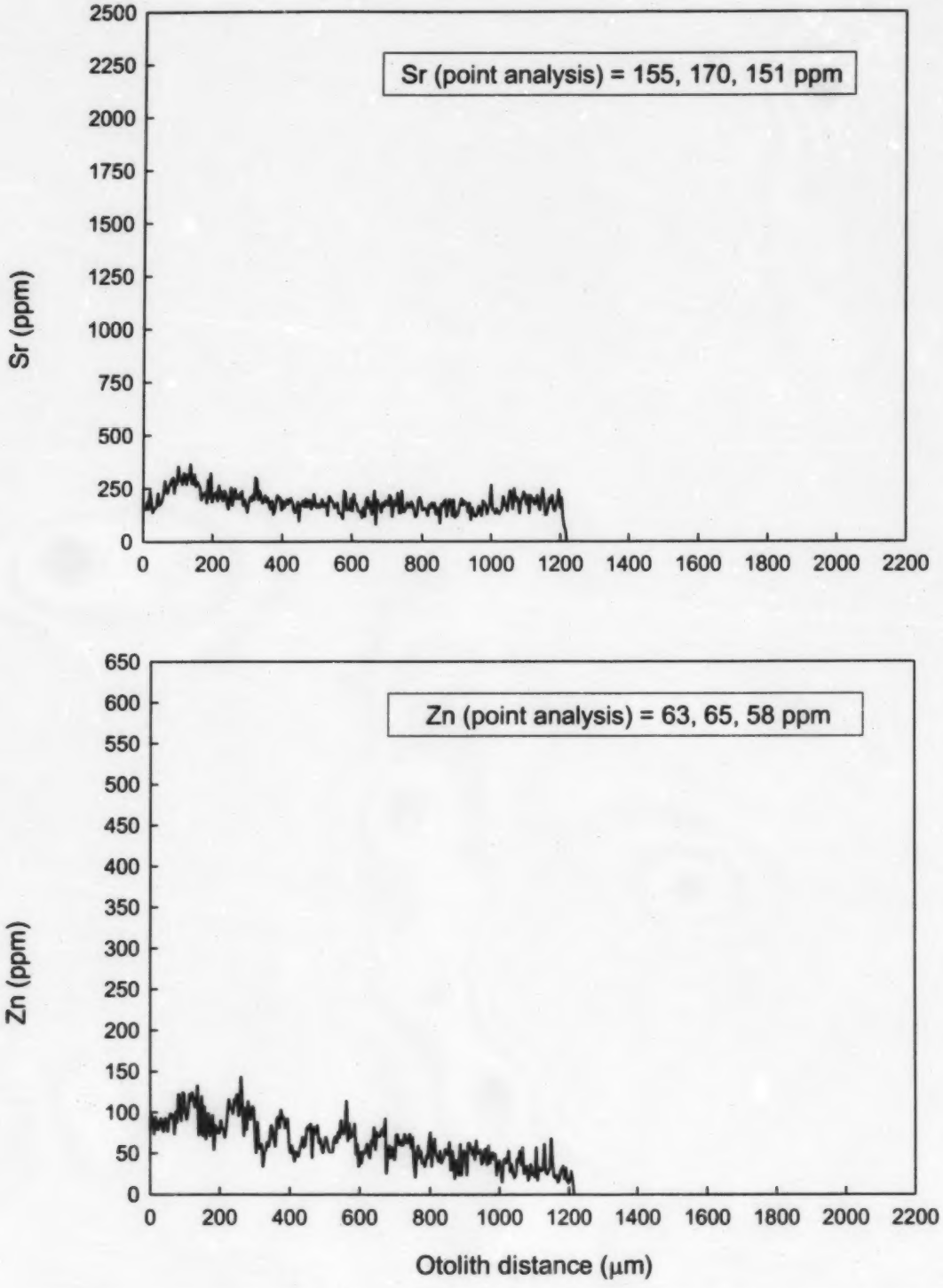

Fig. 135. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (227 mm, 83 g, female, 17 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.

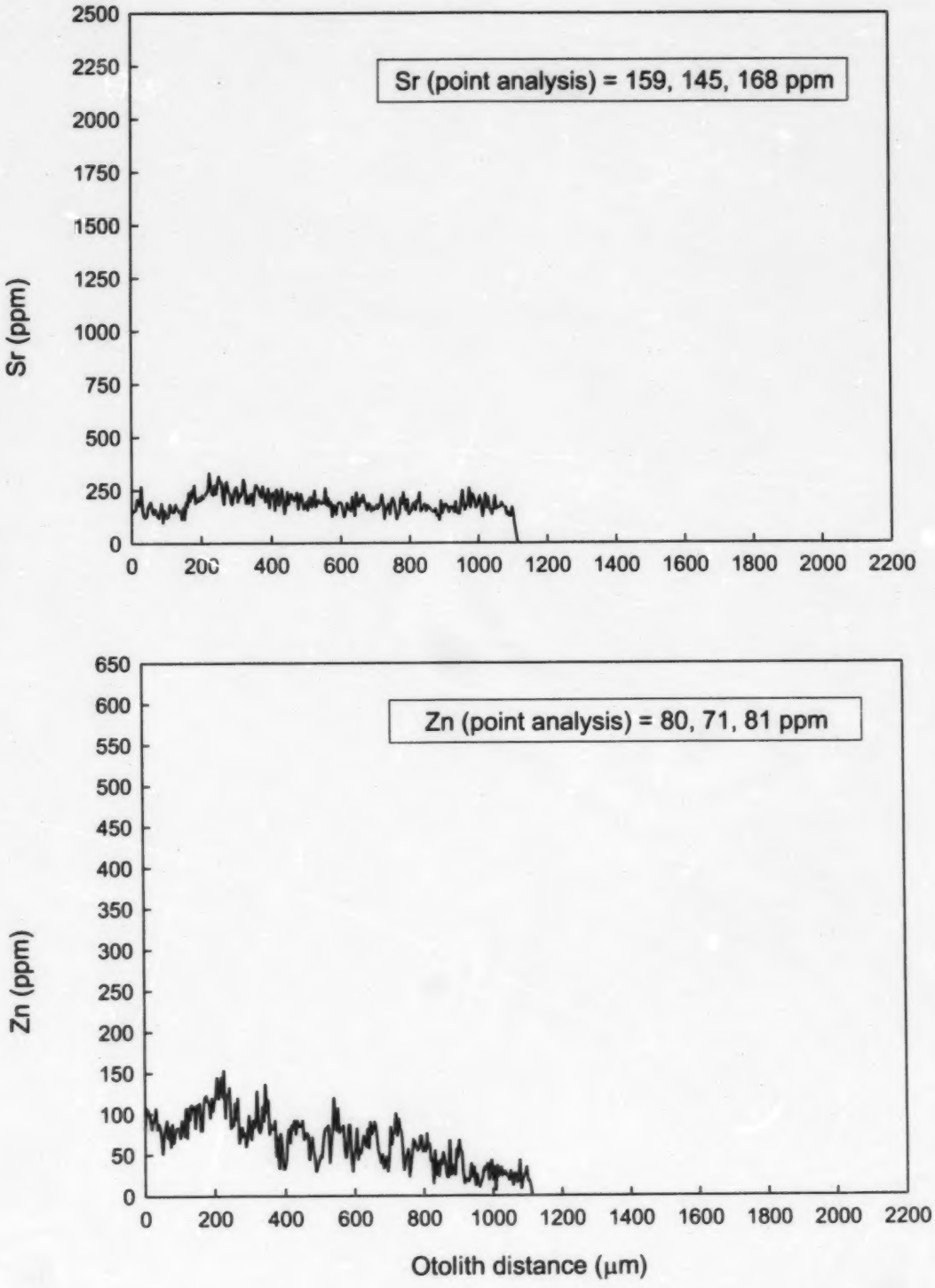

Fig. 136. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (182 mm, 59 g, male, 14 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.

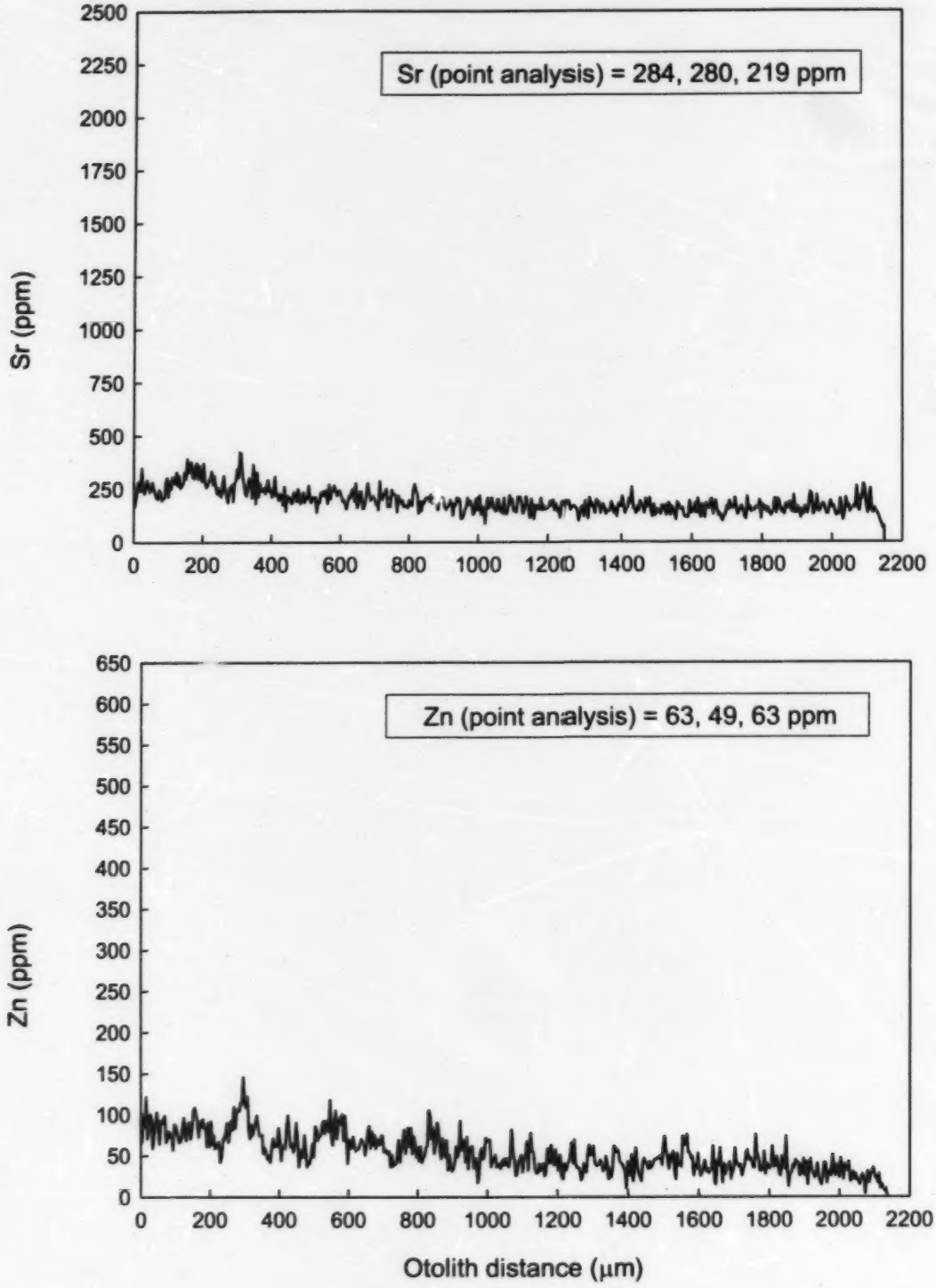

Fig. 137. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (689 mm, 3316 g, male, 27 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.

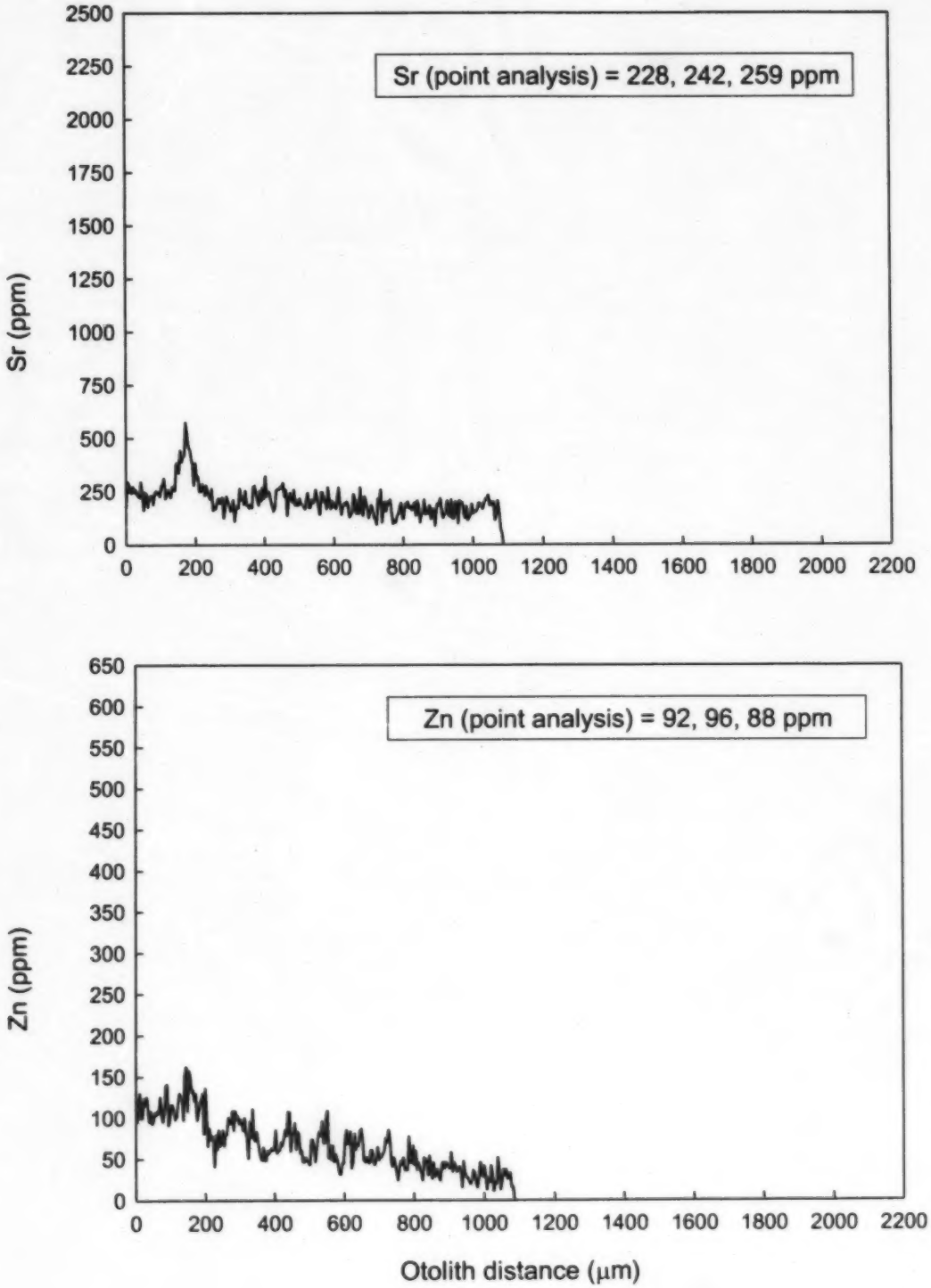

Fig. 138. Strontium (top) and zinc (bottom) profiles from a scanning proton microprobe line-scan of an otolith from an Arctic char (168 mm, 46 g, male, 13 yr) caught in Murray Lake, July 1998. Point analysis results are also indicated.